The Rhythm of Physical Growth

Howard V. Meredith

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THE RHYTHM OF PHYSICAL GROWTH

A STUDY OF EIGHTEEN ANTHROPOMETRIC MEASUREMENTS ON IOWA CITY WHITE MALES RANGING IN AGE BETWEEN BIRTH AND EIGHTEEN YEARS

by

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FOREWORD

Dr. Meredith's study of physical growth is based on over 90,000 values for eighteen anthropometric measures on 1,243 Iowa City white males. It draws upon records accumulated over a period of fourteen years, a program initiated by the late Bird T. Baldwin and carried forward by Professor McCloy.

Means and standard deviations are given for thirty age intervals within the range from one and one-half months to eighteen years. These values constitute tentative norms for male children of American born parents who are significantly above average in socio-economic status. For certain measures they offer the only normative material thus far reported in the literature. But the main findings deal with growth cycles in detail for each of the selected measures. It is shown, for example, that in the eleventh year physical growth strikes a ''low'' for the measurements of bone, as well as for weight, strength of grip, breathing capacity, and thoracic dimensions.

Individual growth curves indicate that prediction of stature can be undertaken with some accuracy (utilizing a T-score or centile technique) between ages six and eleven. Variability in the onset and duration of adolescence appears to invalidate such prediction between the eleventh and eighteenth years.

George D. Stoddard

Office of the Director
Iowa Child Welfare Research Station
University of Iowa
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CHAPTER I

INTRODUCTION

"Everyone has always known that children grow, but the accurate and quantitative study of this growth began at a singularly late period in the history of natural science." (21, p. 173) The early chapters of the history of science were written largely in terms of man's attempts to know and master the world of nature about him. Not until the last quarter of the nineteenth century did anthropologists and workers in allied fields begin in earnest upon the ontogenetic story of the physical growth of man. It is to this relatively recent study that the present investigation purposes to contribute.

CRITERION OF GROWTH

The term "growth" has a variety of connotations. Throughout this study the word is used to denote successive change in the magnitude of an external physical measurement taken upon the human male. Moreover, the successive changes in bodily magnitude which here receive consideration are those of the more or less permanent type and not hourly, daily, or seasonal fluctuations.

This delimitation of the use of the term growth is made in order to be specific with regard to the phenomena which the present study aims to describe and analyze. In no sense is the delimitation an attempt to simplify the biological explanation of the phenomena. A quotation from Scammon (19, p. 1) will make this clear:

> ". . . . equal units of increment at various stages of development often represent very different entities. A pound's gain in weight in an infant is quite a different thing from an equal gain in later life. In the baby this increment represents a gain in brain substance and viscera, as well as an enlargement of other parts of the body; in an adolescent it is primarily an increase in bone and muscle; while in the middle aged it is often but an accumulation of adipose tissue."

Obviously, the entity referred to in the above quotation as "gain in weight" is illustrative of growth phenomena as determined by our criterion. Furthermore, it should now be apparent that it is not the direct concern of this study either to differentiate the mormulation of a fourteen-year measurement program—from September, 1920 to September, 1934—carried on by the anthropometric staff of the Iowa Child Welfare Research Station.

All available records on white males who were not outside the normal zone in physical build were utilized. The records were taken from the file in serial order and were accepted for tabulation unless marked as applying (1) to individuals of the Negroid or Mongoloid races or (2) to white individuals appearing physically pathological.

Complete information with regard to the country of birth of the parents and grandparents of the 1,243 white males on whom the data were collected could not be ascertained, since the records for certain years afforded nothing on these items. However, the country of birth of each parent was found to be recorded for 618 or 50 per cent of the subjects and the country of birth of each grandparent for 376 individuals of this sampling. Analysis of this material yields the following figures:

Country of Birth Parents	Per Cent
One or both parents born in:	
United States	95.3
British Isles or Canada	4.5
North European countries	3.4
South Europe (including Russian Jews)	2.4
Both parents born in United States	90.1

Country of Birth Grandparents	Per Cent
Two or more grandparents born in:	
United States	83.8
British Isles or Canada	9.3
North European countries	12.5
South Europe (including Russian Jews)	5.8
"Old Americans"*	60.4

*Both parents and all four grandparents were born in the United States.

From the point of view of racial stock it appears that the subjects form an exceptionally homogeneous sampling.

The occupation of the father provided the only possible objective approach to the socio-economic status of the males on whom the data were taken. Here, as with birthplace of parents and for the same reason, information was lacking for 633 of the 1,243 subjects.

A sevenfold classification of the 610 recorded observations on parental occupation gives the following gross findings:

Occupation of Father	Per Cent
Professional (mainly members of university faculty)	33.1
Business proprietors, managers, salesmen	20.3
Skilled trade employees	14.1
Farmers*	13.6
Clerks, carriers, etc.	10.2
Students (mostly graduate)	5.5
Laborers	3.2

*This occupation is not evenly distributed over the age range studied. About three-fourths of the observations on which the percentage is based are taken on the fathers of boys who attended the University of Iowa high school without being previously enrolled in its elementary school, preschool laboratories, or infant laboratory.

Most apparent is the predominance of the professional class and the insignificant representation of the laboring class. On the basis of the whole table, it seems reasonable to deduct that the data were gathered on a well-nourished group of males.

In summary, the group on whom the data were taken may be characterized as homogeneous with reference to geographic location and sex, not significantly diverse racially, and somewhat favored economically and culturally.

As mentioned previously, the 93,232 measurement values which constitute the data are divided among eighteen anthropometric measurements. A list of these measurements is furnished below:

Measurement	Observations
Stature	8,437
Sitting height	8,063
Bi-deltoid diameter	7,694
Bi-trochanteric diameter	7,835
Transverse diameter of thorax	7,059
Antero-posterior diameter of thorax	7,027
Thoracic circumference	7,065
Body weight	8,564
Maximum head length	3,523
Maximum head breadth	3,523
Bi-condylar diameter of left femur	2,857
Bi-condylar diameter of left humerus	2,699
Strength of grip	4,999
Breathing capacity	4,307
Skin and subcutaneous tissue at thorax front	2,395
Skin and subcutaneous tissue at thorax back	2,395
Skin and subcutaneous tissue at upperarm front	2,395
Skin and subcutaneous tissue at upperarm back	2,395

Information on the anthropometric instruments, anatomical landmarks, and laboratory technique used in taking the measurements is given in the Appendix. With reference to precision of measurement, the records give body weight to the nearest one-tenth kilogram, breathing capacity to the nearest cubic inch, strength of grip to the nearest kilogram, and all other measurements to the nearest millimeter.

A BURDEN OF PROOF

It has been pointed out (23, p. ii) that research workers have three techniques "which frequently serve to hide the absence of ideas, namely, correlation and probable errors, unnecessary instrumentation, and verbiage." In carrying forward the present investigation continual need has arisen for the use of mathematical constants, graphic instrumentation, and technical terminology. Consequently these devices are used liberally throughout the following chapters. It is the writer's belief that each technique, wherever used, subserves logical considerations. It remains, however, for the study itself to yield evidence that the three devices serve not to "hide the absence of ideas" but rather to facilitate the development and expression of ideas.

CHAPTER II

GROWTH IN THE GROUP: CENTRAL TENDENCY AND VARIABILITY

The data to be analyzed are 93,232 measurement values. These values are distributed among eighteen physical measurement variables and cover observations throughout the age period from birth to eighteen years.

ARRANGEMENT OF DATA

Approaching the analysis logically, the initial problem is that of arranging the data in a manner which will permit them to be economically and meaningfully discussed. This problem, conveniently, is in part resolved by the declared purpose of the analysis. In order to study the "rhythm of growth" for different physical dimensions, it is necessary (1) that the values of each measurement variable receive independent consideration and (2) that the age period over which each variable ranges be divided into relatively small units. Accordingly, each of the eighteen measurements is treated as a distinct continuum, and the age period represented by each measurement variable is cut into numerous segments.

The divisions of the age period adopted are as follows: twelve three-month intervals covering the successive quarter years from birth to three years; seven six-month intervals between three years and six years, six months; twelve one-year intervals between six years, six months and eighteen years, six months. These divisions make a continuous series of thirty-one age intervals for the entire age period. The reasonableness of this allotment becomes apparent upon alignment of such influencing factors as (1) the scope and aims of the study, (2) the known trends of growth with age, and (3) the number of observations available at each interval.

Considering the values of each measurement as now segregated from the values for all other measurements and as grouped according to the age interval within which they were observed, the next necessary step in arrangement is suggested by Yule. He says:

> "If some hundreds or thousands of values of a variable have been noted merely in the arbitrary order in which they happen to occur, the

> mind cannot properly grasp the significance of the record: the observations must be ranked or classified in some way before the characteristics of the series can be comprehended. . . .'' (24, p. 75)

The values of each measurement which fall within each age interval were thus classified into a frequency distribution. There are 529 frequency distributions in all—thirty-one for each of sixteen physical dimensions and a total of thirty-three for two additional measurements. These distributions are given in the appendix of the manuscript copy.[2]

At this point mention of a statistical detail appears relevant. In determining the real limits of the class intervals and in tabulating the data, a measurement value was always interpreted as extending from .5 below its last digit on the right to .5 above this digit. For example, a measurement record of 162.2 cms. for stature is considered to occupy or represent the distance from 162.15 cms. to 162.2499 cms.

MEAN GROWTH

With the data arranged in an orderly form it is now possible to commence analysis. Continuing a logical approach, the problem which emerges is that of describing the frequency distributions formed. Since the distributions appear roughly symmetrical, they may be meaningfully and quantitatively described in terms of central tendency and variability.

Attention will first be concentrated upon central tendency. Here description necessitates a single constant which will summarize the average magnitude of the measurement values tabulated in each frequency distribution. Such a constant is obtained by computing the arithmetic mean of each distribution. Tables 1 to 18 give arithmetic means for the 529 distributions. Tables 15 to 18 inclusive also include median values. This latter measure is given because the distributions of these four tables are characterized by occasional extreme observations which cause the ''aggregate'' mean to exceed markedly the ''typical'' magnitude. Parenthetically, these extreme observations represent skin and subcutaneous tissue measurements for excessively fat, though not pathologically obese, males.

It will be observed that throughout the eighteen tables mentioned above each arithmetic mean is accompanied by its standard error.

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[2] The manuscript copy is on file at the State University of Iowa Library, Iowa City, Iowa.

Table 1

Stature (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group											
Years	Months	Days	Years	Months	Days	Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range*
		0 to		2	30	55	55.44	.53	3.90	7.0	46 to 64
	3	0 to		5	30	117	65.42	.27	2.89	4.4	58 to 73
	6	0 to		8	30	159	70.58	.23	2.85	4.0	64 to 78
	9	0 to		11	30	154	74.83	.23	2.90	3.9	68 to 83
1	0	0 to	1	2	30	145	78.19	.22	2.66	3.4	73 to 87
1	3	0 to	1	5	30	125	81.15	.23	2.51	3.1	73 to 87
1	6	0 to	1	8	30	117	84.43	.26	2.85	3.4	78 to 91
1	9	0 to	1	11	30	103	87.21	.29	2.92	3.4	81 to 98
2	0	0 to	2	2	30	105	89.85	.30	3.11	3.5	82 to 99
2	3	0 to	2	5	30	107	91.11	.31	3.21	3.5	82 to 98
2	6	0 to	2	8	30	141	93.57	.32	3.79	4.0	84 to 104
2	9	0 to	2	11	30	132	95.80	.30	3.47	3.6	87 to 104
3	0	0 to	3	5	30	260	97.84	.21	3.44	3.5	89 to 109
3	6	0 to	3	11	30	305	101.66	.24	4.11	4.0	93 to 113
4	0	0 to	4	5	30	305	104.99	.21	3.69	3.5	95 to 115
4	6	0 to	4	11	30	355	108.48	.21	4.04	3.7	95 to 119
5	0	0 to	5	5	30	445	111.40	.19	4.08	3.7	101 to 123
5	6	0 to	5	11	30	440	114.49	.20	4.27	3.7	105 to 125
6	0	0 to	6	5	30	308	117.41	.24	4.20	3.6	107 to 131
6	6	0 to	7	5	30	575	121.91	.21	4.99	4.1	109 to 137
7	6	0 to	8	5	30	493	128.13	.23	5.09	4.0	115 to 145
8	6	0 to	9	5	30	478	133.71	.25	5.49	4.1	119 to 151
9	6	0 to	10	5	30	390	138.94	.28	5.57	4.0	123 to 153
10	6	0 to	11	5	30	368	143.20	.32	6.06	4.2	127 to 161
11	6	0 to	12	5	30	340	147.81	.34	6.30	4.3	129 to 167
12	6	0 to	13	5	30	345	153.31	.40	7.37	4.8	137 to 173
13	6	0 to	14	5	30	345	159.39	.46	8.53	5.4	140 to 182
14	6	0 to	15	5	30	376	165.15	.45	8.63	5.2	138 to 190
15	6	0 to	16	5	30	343	169.73	.41	7.58	4.5	142 to 190
16	6	0 to	17	5	30	288	173.51	.38	6.39	3.7	146 to 190
17	6	0 to	18	5	30	218	174.15	.42	6.25	3.6	154 to 194

*The minimum and maximum values given in this column are the mid-points of the lowest and highest class interval of each distribution.

Table 4

Bi-Trochanteric Diameter (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days						
		0 to		2	30	32	11.89	.16	.93	7.8	10.0 to 14.0
	3	0 to		5	30	106	14.03	.11	1.12	8.0	11.5 to 18.0
	6	0 to		8	30	160	15.14	.10	1.22	8.1	12.0 to 19.0
	9	0 to		11	30	147	15.63	.09	1.12	7.2	13.0 to 19.5
1	0	0 to	1	2	30	130	15.76	.11	1.22	7.7	13.5 to 19.5
1	3	0 to	1	5	30	111	15.86	.11	1.20	7.6	13.0 to 19.5
1	6	0 to	1	8	30	99	16.35	.11	1.12	6.9	13.0 to 19.5
1	9	0 to	1	11	30	91	16.68	.11	1.02	6.1	14.0 to 19.5
2	0	0 to	2	2	30	103	16.87	.09	.95	5.6	15.5 to 20.5
2	3	0 to	2	5	30	95	17.06	.10	.98	5.7	14.5 to 19.5
2	6	0 to	2	8	30	122	17.46	.10	1.16	6.6	15.0 to 20.5
2	9	0 to	2	11	30	112	17.78	.09	.99	5.6	15.0 to 20.5
3	0	0 to	3	5	30	206	18.12	.07	.95	5.2	15.5 to 20.5
3	6	0 to	3	11	30	248	18.63	.06	1.03	5.5	16.0 to 21.0
4	0	0 to	4	5	30	262	18.99	.05	.85	4.5	16.5 to 21.5
4	6	0 to	4	11	30	306	19.39	.05	.93	4.8	16.5 to 22.0
5	0	0 to	5	5	30	381	19.76	.05	.96	4.9	17.0 to 23.0
5	6	0 to	5	11	30	385	20.18	.06	1.14	5.6	17.5 to 24.5
6	0	0 to	6	5	30	298	20.54	.07	1.16	5.7	17.0 to 24.5
6	6	0 to	7	5	30	547	21.25	.05	1.17	5.5	18.0 to 25.5
7	6	0 to	8	5	30	501	22.20	.06	1.41	6.3	19.0 to 28.0
8	6	0 to	9	5	30	479	23.15	.07	1.61	6.9	19.0 to 30.0
9	6	0 to	10	5	30	388	24.27	.09	1.76	7.2	21.0 to 31.0
10	6	0 to	11	5	30	368	25.02	.10	1.82	7.3	21.0 to 32.0
11	6	0 to	12	5	30	331	26.09	.11	2.03	7.8	22.0 to 33.0
12	6	0 to	13	5	30	334	27.37	.12	2.18	8.0	23.0 to 35.0
13	6	0 to	14	5	30	329	29.47	.15	2.69	9.1	24.0 to 39.0
14	6	0 to	15	5	30	358	30.12	.13	2.38	7.9	24.0 to 39.0
15	6	0 to	16	5	30	329	31.21	.13	2.27	7.3	25.0 to 40.0
16	6	0 to	17	5	30	277	32.09	.12	2.07	6.5	26.0 to 39.0
17	6	0 to	18	5	30	200	32.29	.15	2.11	6.6	27.0 to 39.0

*The figures of this column represent the mid-points of the lowest and highest class interval of each distribution.

Table 5

Transverse Diameter of Thorax* (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range**
Years	Months	Days	Years	Months	Days						
		0 to		2	30	35	12.07	.15	.88	7.3	10.2 to 14.0
	3	0 to		5	30	102	13.84	.09	.88	6.4	12.0 to 16.0
	6	0 to		8	30	158	14.66	.07	.85	5.8	12.5 to 17.0
	9	0 to		11	30	147	15.35	.06	.72	4.7	13.5 to 17.2
1	0	0 to	1	2	30	130	15.69	.07	.76	4.8	14.0 to 17.5
1	3	0 to	1	5	30	110	16.05	.07	.79	4.9	14.2 to 17.7
1	6	0 to	1	8	30	100	16.24	.07	.68	4.2	14.7 to 18.5
1	9	0 to	1	11	30	100	16.55	.08	.85	5.1	14.5 to 20.0
2	0	0 to	2	2	30	92	16.66	.10	.92	5.5	15.0 to 20.0
2	3	0 to	2	5	30	78	16.71	.05	.47	2.8	15.0 to 18.5
2	6	0 to	2	8	30	93	16.83	.10	.95	5.6	14.5 to 19.0
2	9	0 to	2	11	30	85	16.86	.09	.82	4.9	15.5 to 19.0
3	0	0 to	3	5	30	171	17.05	.06	.80	4.7	15.0 to 19.0
3	6	0 to	3	11	30	209	17.36	.06	.84	4.8	15.0 to 19.0
4	0	0 to	4	5	30	219	17.61	.05	.80	4.5	15.0 to 19.5
4	6	0 to	4	11	30	251	17.84	.05	.81	4.5	15.5 to 20.5
5	0	0 to	5	5	30	317	18.15	.05	.93	5.1	15.5 to 21.0
5	6	0 to	5	11	30	326	18.47	.05	.96	5.2	16.0 to 21.0
6	0	0 to	6	5	30	264	18.66	.06	1.03	5.5	15.5 to 21.5
6	6	0 to	7	5	30	515	19.25	.05	1.07	5.6	16.0 to 23.0
7	6	0 to	8	5	30	474	20.01	.06	1.22	6.1	16.0 to 24.5
8	6	0 to	9	5	30	458	20.76	.07	1.42	6.8	17.0 to 27.0
9	6	0 to	10	5	30	366	21.59	.08	1.55	7.2	17.0 to 28.0
10	6	0 to	11	5	30	355	22.14	.09	1.67	7.5	19.0 to 29.0
11	6	0 to	12	5	30	313	22.88	.10	1.85	8.1	19.0 to 31.0
12	6	0 to	13	5	30	294	23.98	.11	1.84	7.7	20.0 to 31.0
13	6	0 to	14	5	30	286	25.05	.12	2.09	8.3	20.0 to 34.0
14	6	0 to	15	5	30	313	25.99	.12	2.11	8.1	21.0 to 34.0
15	6	0 to	16	5	30	282	26.96	.12	1.93	7.2	21.0 to 32.0
16	6	0 to	17	5	30	236	27.68	.13	1.95	7.0	22.0 to 35.0
17	6	0 to	18	5	30	180	28.34	.13	1.73	6.1	23.0 to 33.0

*Measured at the nipple level

**The minimum and maximum values given are the mid-points of the lowest and highest class interval of the distribution to which they apply. Where necessary, the mid-points have been rounded to the nearest one-tenth centimeter so as to avoid spurious accuracy.

Table 6

Antero-Posterior Diameter of Thorax* (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range**
Years	Months	Days	Years	Months	Days						
		0 to		2	30	33	10.23	.12	.69	6.7	8.6 to 11.6
	3	0 to		5	30	102	11.19	.08	.80	7.2	9.6 to 13.4
	6	0 to		8	30	152	11.61	.06	.76	6.6	10.1 to 13.9
	9	0 to		11	30	147	12.01	.06	.70	5.8	10.4 to 13.9
1	0	0 to	1	2	30	130	12.17	.07	.79	6.5	10.6 to 13.9
1	3	0 to	1	5	30	107	12.54	.09	.91	7.3	10.4 to 14.6
1	6	0 to	1	8	30	100	12.64	.08	.82	6.5	11.1 to 14.9
1	9	0 to	1	11	30	95	12.69	.08	.74	5.8	11.1 to 14.6
2	0	0 to	2	2	30	92	12.70	.08	.77	6.1	11.1 to 14.6
2	3	0 to	2	5	30	76	12.56	.09	.74	5.9	10.6 to 14.4
2	6	0 to	2	8	30	93	12.52	.09	.83	6.6	10.4 to 14.9
2	9	0 to	2	11	30	85	12.56	.08	.72	5.7	10.6 to 14.1
3	0	0 to	3	5	30	169	12.67	.05	.60	4.7	10.6 to 14.4
3	6	0 to	3	11	30	206	12.87	.05	.65	5.0	10.9 to 14.6
4	0	0 to	4	5	30	214	13.19	.04	.58	4.4	11.4 to 14.4
4	6	0 to	4	11	30	252	13.31	.04	.71	5.3	11.0 to 15.5
5	0	0 to	5	5	30	317	13.58	.04	.79	5.8	11.5 to 16.5
5	6	0 to	5	11	30	326	13.80	.05	.88	6.4	11.0 to 16.5
6	0	0 to	6	5	30	264	14.07	.06	1.00	7.1	11.0 to 17.5
6	6	0 to	7	5	30	515	14.51	.04	.98	6.8	12.0 to 17.5
7	6	0 to	8	5	30	472	15.00	.05	1.05	7.0	12.0 to 19.0
8	6	0 to	9	5	30	456	15.42	.05	1.14	7.4	12.5 to 19.5
9	6	0 to	10	5	30	366	15.94	.06	1.20	7.5	13.0 to 20.0
10	6	0 to	11	5	30	355	16.25	.07	1.28	7.9	13.0 ot 21.5
11	6	0 to	12	5	30	313	16.98	.09	1.52	9.0	14.0 to 23.0
12	6	0 to	13	5	30	294	17.78	.10	1.73	9.7	14.0 to 25.0
13	6	0 to	14	5	30	286	18.62	.10	1.71	9.2	15.0 to 27.0
14	6	0 to	15	5	30	313	19.31	.10	1.71	8.9	15.0 to 25.0
15	6	0 to	16	5	30	282	20.00	.10	1.66	8.3	16.0 to 26.0
16	6	0 to	17	5	30	235	20.70	.11	1.70	8.2	17.0 to 26.0
17	6	0 to	18	5	30	180	21.53	.13	1.73	8.0	17.0 to 28.0

*Taken at the level of the nipples

**The figures given represent the mid-points of the lowest and highest class interval of the distribution to which they apply. Where necessary, the class values have been rounded to the nearest one-tenth centimeter in order to eliminate spurious accuracy.

Table 7

Thoracic Circumference* (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range**
Years	Months	Days	Years	Months	Days						
		0 to		2	30	35	38.19	.38	2.23	5.8	34.5 to 43.5
	3	0 to		5	30	108	42.37	.21	2.19	5.2	37.5 to 47.5
	6	0 to		8	30	160	44.68	.18	2.29	5.1	39.5 to 51.0
	9	0 to		11	30	147	46.68	.16	1.88	4.0	41.0 to 51.0
1	0	0 to	1	2	30	130	47.76	.18	2.07	4.3	43.0 to 52.5
1	3	0 to	1	5	30	110	48.66	.17	1.82	3.7	45.0 to 53.0
1	6	0 to	1	8	30	100	49.35	.20	1.99	4.0	45.0 to 54.5
1	9	0 to	1	11	30	96	50.11	.21	2.03	4.0	45.5 to 55.0
2	0	0 to	2	2	30	94	50.18	.21	2.00	4.0	46.0 to 55.5
2	3	0 to	2	5	30	75	50.45	.23	2.00	4.0	45.5 to 55.0
2	6	0 to	2	8	30	93	50.81	.22	2.11	4.1	45.5 to 55.5
2	9	0 to	2	11	30	85	50.76	.22	2.06	4.1	45.5 to 56.5
3	0	0 to	3	5	30	178	51.32	.14	1.91	3.7	46.0 to 56.0
3	6	0 to	3	11	30	217	52.26	.16	2.33	4.5	46.0 to 57.0
4	0	0 to	4	5	30	225	53.04	.12	1.81	3.4	47.5 to 57.5
4	6	0 to	4	11	30	247	53.70	.12	1.91	3.6	49.5 to 60.0
5	0	0 to	5	5	30	315	54.90	.13	2.28	4.1	49.0 to 64.0
5	6	0 to	5	11	30	324	55.92	.15	2.63	4.7	50.0 to 66.0
6	0	0 to	6	5	30	261	56.86	.17	2.83	5.0	51.0 to 67.0
6	6	0 to	7	5	30	510	58.65	.14	3.07	5.2	50.0 to 69.0
7	6	0 to	8	5	30	472	60.97	.17	3.67	6.0	50.0 to 80.0
8	6	0 to	9	5	30	452	63.05	.21	4.43	7.0	52.0 to 82.0
9	6	0 to	10	5	30	362	65.65	.26	4.97	7.6	54.0 to 86.0
10	6	0 to	11	5	30	355	67.58	.27	4.99	7.4	56.0 to 88.0
11	6	0 to	12	5	30	317	69.95	.34	6.02	8.6	61.0 to 97.0
12	6	0 to	13	5	30	298	73.28	.32	5.55	7.6	61.0 to 97.0
13	6	0 to	14	5	30	286	76.76	.40	6.77	8.8	65.0 to 109.0
14	6	0 to	15	5	30	316	79.96	.35	6.26	7.8	65.0 to 105.0
15	6	0 to	16	5	30	282	83.20	.37	6.13	7.4	65.0 to 105.0
16	6	0 to	17	5	30	235	85.44	.41	6.24	7.3	69.0 to 109.0
17	6	0 to	18	5	30	180	86.89	.45	6.10	7.0	69.0 to 109.0

*At nipple level

**The minimum and maximum values in this column are the mid-points of the lowest and highest class interval of the distribution to which they are attached.

Table 8

Body Weight (Kilograms): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days						
		0 to		2	30	91	4.23	.11	1.05	24.8	2.5 to 7.0
	3	0 to		5	30	112	7.53	.09	.98	13.0	5.5 to 11.0
	6	0 to		8	30	159	8.97	.09	1.15	12.8	7.0 to 12.5
	9	0 to		11	30	154	10.13	.09	1.06	10.5	7.5 to 13.5
1	0	0 to	1	2	30	145	10.84	.10	1.14	10.5	8.5 to 14.0
1	3	0 to	1	5	30	127	11.40	.11	1.19	10.4	8.5 to 15.0
1	6	0 to	1	8	30	117	12.31	.12	1.32	10.7	9.5 to 16.0
1	9	0 to	1	11	30	106	12.88	.13	1.33	10.3	10.0 to 17.5
2	0	0 to	2	2	30	109	13.58	.13	1.32	9.7	11.0 to 18.0
2	3	0 to	2	5	30	107	13.86	.13	1.31	9.5	11.0 to 17.5
2	6	0 to	2	8	30	142	14.67	.14	1.63	11.1	11.0 to 19.0
2	9	0 to	2	11	30	133	15.04	.12	1.39	9.2	12.0 to 18.5
3	0	0 to	3	5	30	269	15.63	.08	1.31	8.4	12.5 to 20.5
3	6	0 to	3	11	30	318	16.71	.10	1.77	10.6	11.5 to 21.5
4	0	0 to	4	5	30	313	17.47	.09	1.63	9.3	12.5 to 22.5
4	6	0 to	4	11	30	349	18.44	.10	1.83	9.9	13.5 to 23.5
5	0	0 to	5	5	30	445	19.48	.10	2.00	10.3	14.0 to 26.0
5	6	0 to	5	11	30	442	20.45	.11	2.35	11.5	15.0 to 28.0
6	0	0 to	6	5	30	316	21.50	.14	2.46	11.4	15.0 to 30.0
6	6	0 to	7	5	30	598	23.52	.12	2.97	12.6	17.0 to 36.0
7	6	0 to	8	5	30	529	26.34	.16	3.64	13.8	16.0 to 42.0
8	6	0 to	9	5	30	482	28.98	.22	4.77	16.5	18.0 to 48.0
9	6	0 to	10	5	30	390	32.53	.28	5.53	17.0	20.0 to 52.0
10	6	0 to	11	5	30	368	35.29	.33	6.33	17.9	24.0 to 63.0
11	6	0 to	12	5	30	340	38.66	.42	7.70	19.9	27.0 to 69.0
12	6	0 to	13	5	30	345	43.64	.47	8.77	20.1	27.0 to 84.0
13	6	0 to	14	5	30	345	48.62	.53	9.91	20.4	30.0 to 102.0
14	6	0 to	15	5	30	376	54.94	.55	10.61	19.3	30.0 to 102.0
15	6	0 to	16	5	30	337	58.36	.52	9.53	16.3	34.0 to 102.0
16	6	0 to	17	5	30	284	62.42	.55	9.31	14.9	34.0 to 106.0
17	6	0 to	18	5	30	216	64.67	.62	9.10	14.1	42.0 to 106.0

*The figures of this column represent the mid-points of the lowest and highest class interval of each distribution.

Table 9

Maximum Head Length (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days						
		0 to		2	30	23	13.39	.10	.47	3.5	12.5 to 14.4
	3	0 to		5	30	72	14.34	.08	.71	4.9	12.7 to 16.4
	6	0 to		8	30	103	15.05	.06	.64	4.2	13.3 to 16.4
	9	0 to		11	30	126	15.70	.06	.70	4.5	14.3 to 17.4
1	0	0 to	1	2	30	102	15.95	.07	.71	4.5	14.3 to 18.0
1	3	0 to	1	5	30	85	16.34	.08	.73	4.4	14.7 to 18.6
1	6	0 to	1	8	30	82	16.61	.08	.74	4.5	14.5 to 18.4
1	9	0 to	1	11	30	79	16.78	.08	.70	4.2	14.9 to 18.6
2	0	0 to	2	2	30	84	17.04	.07	.68	4.0	15.3 to 18.8
2	3	0 to	2	5	30	73	17.11	.08	.72	4.2	15.7 to 18.8
2	6	0 to	2	8	30	87	17.11	.08	.72	4.2	15.5 to 19.0
2	9	0 to	2	11	30	75	17.20	.08	.66	3.9	15.9 to 18.8
3	0	0 to	3	5	30	103	17.15	.06	.64	3.7	15.7 to 18.8
3	6	0 to	3	11	30	102	17.21	.06	.60	3.5	15.5 to 18.4
4	0	0 to	4	5	30	102	17.34	.06	.62	3.6	15.5 to 18.8
4	6	0 to	4	11	30	113	17.52	.05	.58	3.3	15.7 to 18.6
5	0	0 to	5	5	30	126	17.65	.06	.64	3.6	15.7 to 19.2
5	6	0 to	5	11	30	135	17.75	.06	.67	3.8	15.9 to 19.2
6	0	0 to	6	5	30	128	17.78	.06	.66	3.7	16.1 to 19.2
6	6	0 to	7	5	30	175	17.87	.05	.63	3.6	16.1 to 19.4
7	6	0 to	8	5	30	166	17.98	.05	.62	3.4	16.3 to 19.2
8	6	0 to	9	5	30	167	18.15	.05	.61	3.4	16.3 to 19.8
9	6	0 to	10	5	30	145	18.36	.05	.63	3.4	16.7 to 20.0
10	6	0 to	11	5	30	157	18.40	.05	.63	3.4	16.9 to 19.8
11	6	0 to	12	5	30	153	18.53	.05	.63	3.4	17.1 to 20.0
12	6	0 to	13	5	30	127	18.66	.06	.64	3.4	17.1 to 20.0
13	6	0 to	14	5	30	120	18.75	.05	.60	3.2	17.3 to 20.2
14	6	0 to	15	5	30	134	18.90	.06	.64	3.4	17.5 to 20.4
15	6	0 to	16	5	30	140	19.13	.05	.59	3.1	17.9 to 20.6
16	6	0 to	17	5	30	129	19.32	.05	.57	3.0	17.9 to 20.6
17	6	0 to	18	5	30	110	19.32	.06	.66	3.4	17.9 to 20.8

*The values given in this column are the mid-points of the extreme class interval of each distribution. In order to avoid spurious accuracy the mid-points have been rounded to the nearest one-tenth centimeter.

Table 10

Maximum Head Breadth (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days						
		0 to		2	30	23	10.91	.11	.51	4.6	10.3 to 12.0
	3	0 to		5	30	72	11.86	.08	.66	5.6	10.7 to 13.6
	6	0 to		8	30	103	12.63	.06	.61	5.2	11.3 to 14.0
	9	0 to		11	30	126	12.96	.05	.54	4.2	11.9 to 14.4
1	0	0 to	1	2	30	102	13.18	.06	.57	4.3	12.1 to 14.8
1	3	0 to	1	5	30	85	13.43	.06	.53	4.0	12.1 to 15.0
1	6	0 to	1	8	30	82	13.55	.05	.49	3.6	12.5 to 15.2
1	9	0 to	1	11	30	79	13.63	.06	.49	3.6	12.5 to 15.0
2	0	0 to	2	2	30	84	13.75	.06	.52	3.8	12.7 to 15.0
2	3	0 to	2	5	30	73	13.80	.06	.51	3.7	12.7 to 15.2
2	6	0 to	2	8	30	87	13.90	.06	.55	4.0	12.5 to 15.0
2	9	0 to	2	11	30	75	13.92	.07	.57	4.8	12.3 to 15.0
3	0	0 to	3	5	30	103	13.97	.06	.60	4.3	12.7 to 15.4
3	6	0 to	3	11	30	102	14.16	.06	.60	4.2	12.7 to 15.2
4	0	0 to	4	5	30	102	14.23	.06	.56	4.0	12.7 to 15.6
4	6	0 to	4	11	30	113	14.31	.05	.56	3.9	12.9 to 15.6
5	0	0 to	5	5	30	126	14.38	.05	.54	3.7	12.9 to 16.0
5	6	0 to	5	11	30	135	14.41	.05	.54	3.8	13.1 to 16.0
6	0	0 to	6	5	30	128	14.39	.04	.49	3.4	13.1 to 16.2
6	6	0 to	7	5	30	175	14.48	.04	.49	3.4	13.1 to 16.4
7	6	0 to	8	5	30	166	14.62	.04	.52	3.6	13.3 to 16.6
8	6	0 to	9	5	30	167	14.70	.04	.55	3.7	13.3 to 16.6
9	6	0 to	10	5	30	145	14.77	.04	.53	3.6	13.3 to 16.4
10	6	0 to	11	5	30	157	14.79	.04	.53	3.6	13.5 to 16.6
11	6	0 to	12	5	30	153	14.85	.04	.50	3.4	13.7 to 16.4
12	6	0 to	13	5	30	127	14.95	.05	.57	3.8	13.9 to 16.4
13	6	0 to	14	5	30	120	14.99	.05	.52	3.5	14.1 to 16.6
14	6	0 to	15	5	30	134	15.09	.05	.54	3.6	13.9 to 16.8
15	6	0 to	16	5	30	140	15.12	.04	.51	3.4	14.1 to 16.6
16	6	0 to	17	5	30	129	15.24	.04	.49	3.2	14.3 to 16.6
17	6	0 to	18	5	30	110	15.28	.05	.49	3.2	14.1 to 16.6

*The minimum and maximum values given are the mid-points of the extreme class interval of each distribution. Spurious accuracy has been eliminated by rounding the class values to the nearest one-tenth centimeter.

Table 11

Bi-Condylar Diameter of Left Femur (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range**
Years	Months	Days	Years	Months	Days						
		0 to		2	30	15*	4.25	.05	.20	4.7	3.9 to 4.7
	3	0 to		5	30	58	4.87	.05	.37	7.6	4.3 to 5.9
	6	0 to		8	30	78	5.22	.05	.44	8.4	4.5 to 6.4
	9	0 to		11	30	81	5.41	.05	.44	8.1	4.6 to 6.8
1	0	0 to	1	2	30	68	5.63	.05	.43	7.6	4.7 to 6.7
1	3	0 to	1	5	30	67	5.81	.06	.46	7.9	4.8 to 6.8
1	6	0 to	1	8	30	56	5.95	.06	.43	7.2	5.0 to 7.0
1	9	0 to	1	11	30	44	6.03	.06	.42	7.0	5.2 to 7.2
2	0	0 to	2	2	30	52	6.23	.05	.38	6.1	5.5 to 7.2
2	3	0 to	2	5	30	48	6.33	.05	.36	5.7	5.5 to 7.4
2	6	0 to	2	8	30	56	6.52	.06	.44	6.7	5.7 to 7.6
2	9	0 to	2	11	30	41	6.66	.05	.31	4.7	5.9 to 7.5
3	0	0 to	3	5	30	76	6.82	.03	.27	4.0	6.1 to 7.6
3	6	0 to	3	11	30	83	6.98	.03	.28	4.0	6.2 to 7.5
4	0	0 to	4	5	30	93	7.10	.03	.27	3.8	6.5 to 7.9
4	6	0 to	4	11	30	101	7.20	.03	.29	4.0	6.6 to 8.2
5	0	0 to	5	5	30	126	7.34	.03	.29	4.0	6.7 to 8.3
5	6	0 to	5	11	30	132	7.41	.03	.38	5.1	6.5 to 8.5
6	0	0 to	6	5	30	102	7.52	.03	.33	4.4	6.6 to 8.3
6	6	0 to	7	5	30	169	7.75	.03	.41	5.3	6.7 to 8.6
7	6	0 to	8	5	30	137	8.08	.04	.43	5.3	7.1 to 9.0
8	6	0 to	9	5	30	135	8.28	.04	.47	5.7	7.3 to 9.6
9	6	0 to	10	5	30	126	8.48	.05	.54	6.4	7.3 to 9.8
10	6	0 to	11	5	30	121	8.56	.05	.50	5.8	7.3 to 9.8
11	6	0 to	12	5	30	106	8.85	.06	.57	6.4	7.5 to 10.2
12	6	0 to	13	5	30	120	9.23	.06	.60	6.5	7.9 to 10.6
13	6	0 to	14	5	30	116	9.52	.06	.65	6.8	7.9 to 11.4
14	6	0 to	15	5	30	147	9.57	.05	.55	5.8	8.3 to 11.6
15	6	0 to	16	5	30	128	9.63	.05	.57	5.9	8.3 to 11.8
16	6	0 to	17	5	30	103	9.68	.05	.48	5.0	8.7 to 11.0
17	6	0 to	18	5	30	72	9.68	.07	.57	5.9	8.7 to 11.6

*Paucity of cases is recognized to make analysis of this distribution of questionable value.

**The figures of this column represent the mid-points of the lowest and highest class interval of each distribution. In some instances the class values have been rounded.

Table 12

Bi-Condylar Diameter of Left Humerus (Centimeters): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group											
Years	Months	Days	Years	Months	Days	Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range**
		0 to		2	30	15*	3.13	.03	.11	3.5	3.0 to 3.4
	3	0 to		5	30	58	3.49	.03	.25	7.2	3.0 to 4.0
	6	0 to		8	30	78	3.71	.03	.30	8.1	3.2 to 4.6
	9	0 to		11	30	82	3.89	.03	.31	8.0	3.1 to 4.7
1	0	0 to	1	2	30	69	3.98	.04	.30	7.5	3.3 to 4.6
1	3	0 to	1	5	30	65	4.08	.04	.29	7.1	3.5 to 5.0
1	6	0 to	1	8	30	55	4.12	.05	.38	9.2	3.2 to 5.2
1	9	0 to	1	11	30	44	4.13	.04	.28	6.8	3.6 to 5.2
2	0	0 to	2	2	30	53	4.18	.03	.24	5.7	3.7 to 4.8
2	3	0 to	2	5	30	41	4.30	.04	.27	6.3	3.7 to 4.9
2	6	0 to	2	8	30	47	4.36	.04	.31	7.1	3.7 to 5.0
2	9	0 to	2	11	30	29	4.62	.04	.24	5.2	4.1 to 5.0
3	0	0 to	3	5	30	56	4.71	.04	.27	5.7	4.3 to 5.3
3	6	0 to	3	11	30	55	4.70	.03	.23	4.9	4.4 to 5.2
4	0	0 to	4	5	30	67	4.70	.03	.22	4.7	4.3 to 5.3
4	6	0 to	4	11	30	76	4.80	.03	.28	5.8	4.2 to 5.7
5	0	0 to	5	5	30	106	4.80	.03	.27	5.6	4.2 to 5.6
5	6	0 to	5	11	30	120	4.85	.03	.28	5.8	4.1 to 5.6
6	0	0 to	6	5	30	102	4.93	.03	.26	5.3	4.3 to 5.8
6	6	0 to	7	5	30	169	5.09	.02	.30	5.9	4.2 to 5.7
7	6	0 to	8	5	30	137	5.30	.03	.30	5.7	4.6 to 6.1
8	6	0 to	9	5	30	135	5.48	.03	.36	6.6	4.7 to 6.5
9	6	0 to	10	5	30	126	5.57	.03	.38	6.8	4.5 to 6.4
10	6	0 to	11	5	30	121	5.61	.03	.33	5.9	4.7 to 6.7
11	6	0 to	12	5	30	106	5.80	.04	.43	7.4	5.0 to 7.1
12	6	0 to	13	5	30	120	6.05	.04	.45	7.4	5.2 to 7.5
13	6	0 to	14	5	30	116	6.38	.04	.45	7.1	5.4 to 7.5
14	6	0 to	15	5	30	148	6.54	.04	.43	6.6	5.6 to 7.9
15	6	0 to	16	5	30	128	6.71	.04	.40	6.0	5.8 to 7.7
16	6	0 to	17	5	30	103	6.84	.05	.46	6.7	6.0 to 8.3
17	6	0 to	18	5	30	72	6.97	.05	.43	6.2	6.4 to 7.9

*This distribution is included for completeness. The paucity of observations is acknowledged.

**The minimum and maximum values given are the mid-points of the lowest and highest class interval of the distribution to which they apply. The mid-points have been rounded, where necessary, so as to avoid spurious accuracy.

Table 13

Strength of Grip* (Kilograms): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Nineteen Distributions of Iowa City White Males, Covering the Age Period from Three Years to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range**
Years	Months	Days	Years	Months	Days						
3	0	0 to	3	5	30	41	5.05	.27	1.74	34.5	2 to 9
3	6	0 to	3	11	30	69	6.93	.25	2.05	29.6	2 to 13
4	0	0 to	4	5	30	105	8.12	.20	2.07	25.5	4 to 14
4	6	0 to	4	11	30	144	9.69	.19	2.34	24.1	5 to 15
5	0	0 to	5	5	30	173	10.61	.17	2.17	20.5	5 to 18
5	6	0 to	5	11	30	211	11.06	.17	2.49	22.5	4 to 17
6	0	0 to	6	5	30	224	11.73	.17	2.53	21.6	5 to 20
6	6	0 to	7	5	30	469	12.96	.14	3.00	23.1	5 to 21
7	6	0 to	8	5	30	404	15.79	.16	3.15	19.9	7 to 24
8	6	0 to	9	5	30	366	17.89	.19	3.55	19.8	9 to 28
9	6	0 to	10	5	30	325	20.32	.21	3.76	18.5	11 to 30
10	6	0 to	11	5	30	309	22.48	.23	3.95	17.6	15 to 34
11	6	0 to	12	5	30	293	24.98	.26	4.47	17.9	15 to 42
12	6	0 to	13	5	30	333	29.16	.33	5.93	20.3	17 to 52
13	6	0 to	14	5	30	331	33.91	.40	7.31	21.6	18 to 61
14	6	0 to	15	5	30	358	38.86	.45	8.57	22.1	18 to 65
15	6	0 to	16	5	30	342	44.75	.48	8.89	19.9	14 to 69
16	6	0 to	17	5	30	292	48.29	.48	8.19	17.0	21 to 68
17	6	0 to	18	5	30	210	52.42	.60	8.72	16.6	29 to 80

*This measurement was taken with right and left hands independently and the better record used.

**The figures of this column represent the mid-points of the lowest and highest class interval of each distribution. The class values have been rounded, where necessary, to the nearest kilogram.

If three times the standard error of a mean is both added to and subtracted from the mean, an estimate is obtained of the range over which the means for a successive series of similar samplings of the measurement, taken at random, are likely to fluctuate. Disregarding two other possible sources of error, the standard errors of the means indicate the trustworthiness of the means as a basis for generalization.

The two other possible sources of error are those due to anthropometric technique and to grouping for statistical treatment. With

Table 14

Breathing Capacity (Cubic Inches): Mean, Standard Error of Mean, Standard Deviation, Coefficient of Variation, and Range for Fourteen Distributions of Iowa City White Males, Covering the Age Period from Five Years, Six Months to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days						
5	6	0 to	5	11	30	64	66.72	1.53	12.22	18.3	35 to 95
6	0	0 to	6	5	30	151	71.62	1.06	13.00	18.2	35 to 115
6	6	0 to	7	5	30	384	78.54	.69	13.50	17.2	35 to 115
7	6	0 to	8	5	30	386	92.45	.75	14.82	16.0	50 to 135
8	6	0 to	9	5	30	410	103.46	.80	16.16	15.6	55 to 145
9	6	0 to	10	5	30	367	115.50	.97	18.54	16.1	60 to 169
10	6	0 to	11	5	30	346	127.54	1.11	20.61	16.2	80 to 209
11	6	0 to	12	5	30	307	141.91	1.26	22.11	15.6	90 to 199
12	6	0 to	13	5	30	339	157.44	1.57	28.90	18.4	90 to 259
13	6	0 to	14	5	30	333	179.89	2.07	37.82	21.0	90 to 309
14	6	0 to	15	5	30	369	203.81	2.22	42.60	20.9	90 to 349
15	6	0 to	16	5	30	342	227.45	2.17	40.16	17.7	90 to 369
16	6	0 to	17	5	30	294	247.46	2.63	45.06	18.2	130 to 389
17	6	0 to	18	5	30	215	257.22	2.79	40.90	15.9	130 to 409

*The minimum and maximum values given in this column are the mid-points of the extreme class interval of each distribution. The mid-points have been rounded, where necessary, to the nearest cubic inch.

reference to the former, it is assumed that the refined technique used in gathering the data (given in the Appendix) has reduced measurement inaccuracies and bias to a minimum. In the case of the latter, there is a possibility of error due to grouping into age intervals and also due to grouping within class intervals. It is a statistical commonplace that the errors resulting from grouping into class intervals tend to cancel when the distributions are symmetrical. The error arising from age grouping should be recognized even though it is customarily regarded as inconsequential. It is the slight error which is likely to follow from assuming that the mean of a series of measurement observations represents the exact mid-point of the age interval in which the observations are grouped. Actually, the calculated mean of the ages (taken in years,

Table 15

Skin and Subcutaneous Tissue at Thorax Front (Millimeters): Mean, Standard Error of Mean, Median, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Median	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days							
		0 to		2	30	11	3.8	.30	3.6	1.01	26.3	10 to 17
	3	0 to		5	30	38	4.4	.18	4.4	1.10	24.9	11 to 20
	6	0 to		8	30	48	4.0	.13	3.9	.92	23.2	10 to 18
	9	0 to		11	30	59	3.6	.10	3.5	.75	20.7	11 to 17
1	0	0 to	1	2	30	53	3.5	.12	3.5	.90	25.6	10 to 18
1	3	0 to	1	5	30	52	3.7	.11	3.7	.82	22.0	11 to 18
1	6	0 to	1	8	30	45	3.5	.10	3.4	.68	19.6	10 to 16
1	9	0 to	1	11	30	36	3.4	.12	3.4	.71	20.8	9 to 15
2	0	0 to	2	2	30	46	3.3	.10	3.2	.68	20.2	11 to 16
2	3	0 to	2	5	30	35	3.3	.13	3.2	.75	22.9	10 to 18
2	6	0 to	2	8	30	47	3.3	.11	3.2	.75	23.0	10 to 15
2	9	0 to	2	11	30	35	3.5	.14	3.4	.81	23.4	10 to 18
3	0	0 to	3	5	30	59	3.5	.10	3.4	.74	21.1	10 to 16
3	6	0 to	3	11	30	69	3.4	.09	3.2	.78	22.7	10 to 16
4	0	0 to	4	5	30	74	3.2	.08	3.0	.73	23.0	10 to 16
4	6	0 to	4	11	30	70	3.1	.09	3.0	.76	24.3	9 to 16
5	0	0 to	5	5	30	90	3.0	.08	2.9	.72	23.7	9 to 16
5	6	0 to	5	11	30	111	3.1	.08	3.0	.85	27.3	9 to 20
6	0	0 to	6	5	30	80	2.9	.09	2.8	.76	26.8	9 to 18
6	6	0 to	7	5	30	142	3.1	.07	2.9	.83	27.2	10 to 19
7	6	0 to	8	5	30	107	3.3	.10	3.1	1.06	32.5	9 to 20
8	6	0 to	9	5	30	115	3.6	.13	3.4	1.42	39.3	10 to 25
9	6	0 to	10	5	30	104	3.5	.12	3.2	1.18	33.5	9 to 20
10	6	0 to	11	5	30	97	4.0	.16	3.7	1.56	39.3	10 to 26
11	6	0 to	12	5	30	91	4.2	.24	3.5	2.29	54.8	10 to 34
12	6	0 to	13	5	30	117	4.6	.17	4.3	1.85	40.7	10 to 36
13	6	0 to	14	5	30	116	4.7	.17	4.4	1.79	37.9	11 to 33
14	6	0 to	15	5	30	147	4.8	.14	4.4	1.68	34.7	10 to 28
15	6	0 to	16	5	30	128	4.7	.16	4.4	1.78	38.2	11 to 36
16	6	0 to	17	5	30	103	4.7	.14	4.5	1.37	29.0	11 to 30
17	6	0 to	18	5	30	70	4.8	.20	4.6	1.69	35.0	12 to 34

*The minimum and maximum values given are the mid-points of the lowest and highest class interval of the distribution to which they apply.

Table 16

Skin and Subcutaneous Tissue at Thorax Back (Millimeters): Mean, Standard Error of Mean, Median, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Median	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days							
		0 to		2	30	11	4.3	.22	4.4	.72	16.8	11 to 16
	3	0 to		5	30	38	4.9	.16	4.9	1.00	20.6	12 to 21
	6	0 to		8	30	48	4.4	.16	4.2	1.11	25.1	11 to 21
	9	0 to		11	30	59	4.2	.10	4.3	.78	18.4	11 to 17
1	0	0 to	1	2	30	53	4.2	.13	4.3	.97	22.9	10 to 19
1	3	0 to	1	5	30	52	4.3	.13	4.2	.93	21.9	11 to 20
1	6	0 to	1	8	30	45	4.2	.12	4.2	.81	19.0	11 to 18
1	9	0 to	1	11	30	36	4.1	.12	4.2	.71	17.2	10 to 17
2	0	0 to	2	2	30	46	4.0	.10	3.7	.69	17.4	11 to 18
2	3	0 to	2	5	30	35	3.9	.13	3.8	.79	20.3	11 to 18
2	6	0 to	2	8	30	47	4.1	.14	3.9	.98	24.0	10 to 19
2	9	0 to	2	11	30	35	4.3	.13	4.4	.78	18.1	11 to 19
3	0	0 to	3	5	30	59	4.4	.11	4.4	.81	18.5	12 to 19
3	6	0 to	3	11	30	69	4.1	.09	4.1	.71	17.5	11 to 18
4	0	0 to	4	5	30	74	3.8	.08	3.9	.68	17.8	11 to 16
4	6	0 to	4	11	30	70	3.6	.10	3.6	.82	22.5	10 to 17
5	0	0 to	5	5	30	90	3.8	.08	3.8	.77	20.5	10 to 18
5	6	0 to	5	11	30	111	3.8	.08	3.8	.79	21.0	10 to 19
6	0	0 to	6	5	30	80	3.6	.09	3.4	.79	22.1	11 to 19
6	6	0 to	7	5	30	142	3.9	.08	3.8	.90	23.1	11 to 20
7	6	0 to	8	5	30	107	4.0	.10	3.9	1.06	26.5	11 to 22
8	6	0 to	9	5	30	115	4.1	.11	3.9	1.16	28.6	11 to 24
9	6	0 to	10	5	30	104	4.0	.10	3.8	1.05	26.1	10 to 21
10	6	0 to	11	5	30	97	4.3	.10	4.1	1.03	24.0	11 to 22
11	6	0 to	12	5	30	91	4.4	.19	4.0	1.79	40.5	11 to 32
12	6	0 to	13	5	30	117	4.7	.15	4.4	1.63	34.9	12 to 33
13	6	0 to	14	5	30	116	4.8	.12	4.5	1.32	27.8	11 to 26
14	6	0 to	15	5	30	147	4.9	.11	4.6	1.29	26.4	11 to 25
15	6	0 to	16	5	30	128	5.0	.14	4.7	1.57	31.5	12 to 34
16	6	0 to	17	5	30	103	5.2	.14	4.9	1.41	27.1	12 to 32
17	6	0 to	18	5	30	70	5.4	.20	5.1	1.67	30.7	12 to 34

*The figures of this column represent the mid-points of the lowest and highest class interval of each distribution.

Table 17

Skin and Subcutaneous Tissue at Upperarm Front (Millimeters): Mean, Standard Error of Mean, Median, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Median	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days							
		0 to		2	30	11	3.6	.20	3.8	.68	18.6	11 to 15
	3	0 to		5	30	38	4.4	.14	4.3	.89	20.4	12 to 18
	6	0 to		8	30	48	4.7	.13	4.6	.92	19.7	11 to 19
	9	0 to		11	30	59	4.2	.10	4.1	.80	19.2	11 to 19
1	0	0 to	1	2	30	53	4.3	.13	4.4	.98	23.1	11 to 18
1	3	0 to	1	5	30	52	4.3	.10	4.3	.72	16.9	11 to 19
1	6	0 to	1	8	30	45	4.2	.11	4.2	.74	17.7	11 to 18
1	9	0 to	1	11	30	36	3.9	.12	3.9	.69	18.0	10 to 18
2	0	0 to	2	2	30	46	3.9	.12	3.7	.82	20.9	12 to 19
2	3	0 to	2	5	30	36	3.7	.10	3.6	.59	16.1	11 to 17
2	6	0 to	2	8	30	47	4.1	.14	3.7	.97	23.9	12 to 20
2	9	0 to	2	11	30	35	4.0	.12	4.0	.70	17.3	11 to 18
3	0	0 to	3	5	30	60	4.4	.14	4.2	1.05	23.9	12 to 20
3	6	0 to	3	11	30	69	4.2	.12	4.1	1.03	24.7	12 to 20
4	0	0 to	4	5	30	74	4.4	.14	4.1	1.24	28.3	11 to 21
4	6	0 to	4	11	30	70	4.1	.12	4.0	.98	24.1	11 to 19
5	0	0 to	5	5	30	90	4.1	.09	4.2	.83	20.4	11 to 19
5	6	0 to	5	11	30	111	4.0	.10	3.9	1.05	26.4	9 to 20
6	0	0 to	6	5	30	80	3.5	.12	3.2	1.05	29.9	10 to 19
6	6	0 to	7	5	30	142	3.7	.09	3.6	1.12	30.5	10 to 21
7	6	0 to	8	5	30	107	3.7	.12	3.6	1.19	32.6	8 to 22
8	6	0 to	9	5	30	115	3.8	.13	3.6	1.41	37.3	10 to 27
9	6	0 to	10	5	30	104	3.7	.13	3.5	1.32	35.5	9 to 22
10	6	0 to	11	5	30	97	4.1	.12	3.8	1.18	28.9	10 to 20
11	6	0 to	12	5	30	91	4.0	.20	3.5	1.87	47.1	10 to 28
12	6	0 to	13	5	30	117	4.0	.14	3.7	1.52	38.1	9 to 30
13	6	0 to	14	5	30	116	3.9	.13	3.6	1.35	34.8	10 to 25
14	6	0 to	15	5	30	147	3.6	.11	3.2	1.33	36.9	9 to 22
15	6	0 to	16	5	30	128	3.3	.12	3.0	1.35	40.4	10 to 28
16	6	0 to	17	5	30	103	3.3	.11	3.0	1.09	33.5	10 to 23
17	6	0 to	18	5	30	70	3.2	.16	2.9	1.34	41.7	10 to 30

*The minimum and maximum values afforded in this column are the mid-points of the extreme class interval of each distribution.

Table 18

Skin and Subcutaneous Tissue at Upperarm Back (Millimeters): Mean, Standard Error of Mean, Median, Standard Deviation, Coefficient of Variation, and Range for Thirty-One Distributions of Iowa City White Males, Covering the Age Period from Birth to Eighteen Years

Age Group						Cases	Mean	Standard Error of Mean	Median	Standard Deviation	Coefficient of Variation	Range*
Years	Months	Days	Years	Months	Days							
		0 to		2	30	11	4.9	.33	5.0	1.08	22.1	13 to 20
	3	0 to		5	30	38	5.5	.15	5.4	.90	16.3	14 to 20
	6	0 to		8	30	48	5.8	.17	5.6	1.20	20.7	13 to 25
	9	0 to		11	30	59	5.7	.13	5.7	.98	17.3	13 to 23
1	0	0 to	1	2	30	53	5.8	.15	5.9	1.11	19.2	13 to 23
1	3	0 to	1	5	30	52	5.8	.15	5.9	1.07	18.3	14 to 24
1	6	0 to	1	8	30	45	5.6	.15	5.7	.99	17.7	13 to 22
1	9	0 to	1	11	30	36	5.5	.14	5.5	.85	15.4	13 to 22
2	0	0 to	2	2	30	46	5.6	.15	5.6	1.05	18.6	14 to 22
2	3	0 to	2	5	30	36	5.8	.16	5.8	.97	16.9	14 to 22
2	6	0 to	2	8	30	47	5.7	.18	5.8	1.23	21.8	12 to 25
2	9	0 to	2	11	30	35	5.9	.15	5.9	.89	15.1	13 to 22
3	0	0 to	3	5	30	60	6.2	.12	6.3	.96	15.3	13 to 25
3	6	0 to	3	11	30	69	6.1	.12	6.0	.96	15.8	13 to 24
4	0	0 to	4	5	30	74	6.0	.13	5.8	1.09	18.2	14 to 24
4	6	0 to	4	11	30	70	6.0	.11	6.0	.95	15.9	15 to 22
5	0	0 to	5	5	30	90	5.8	.11	5.9	1.05	18.3	12 to 22
5	6	0 to	5	11	30	111	5.8	.10	5.7	1.05	18.0	13 to 24
6	0	0 to	6	5	30	80	5.8	.13	5.8	1.19	20.7	11 to 25
6	6	0 to	7	5	30	142	6.1	.10	5.9	1.24	20.5	10 to 26
7	6	0 to	8	5	30	107	6.2	.14	6.1	1.41	22.6	12 to 28
8	6	0 to	9	5	30	115	6.4	.15	6.3	1.65	25.8	12 to 31
9	6	0 to	10	5	30	104	6.4	.15	6.4	1.55	24.3	11 to 26
10	6	0 to	11	5	30	97	6.9	.16	6.7	1.62	23.4	14 to 30
11	6	0 to	12	5	30	91	6.9	.23	6.7	2.18	31.6	13 to 35
12	6	0 to	13	5	30	117	6.7	.18	6.3	1.99	29.9	13 to 38
13	6	0 to	14	5	30	116	6.4	.17	6.0	1.85	29.1	12 to 32
14	6	0 to	15	5	30	147	5.8	.14	5.5	1.71	29.4	11 to 28
15	6	0 to	16	5	30	128	5.4	.16	5.0	1.82	33.6	11 to 35
16	6	0 to	17	5	30	103	5.5	.16	5.4	1.66	30.5	11 to 32
17	6	0 to	18	5	30	70	5.4	.21	5.1	1.76	32.7	10 to 30

*The figures given are the mid-points of the lowest and highest class interval of the distribution to which they are attached.

months, and days) included within a given age interval would but rarely be found to coincide with the mid-point of the age interval.

As stated earlier, mean values are presented in Tables 1 to 18. It will be noted that each table gives, at frequent and successive age intervals, the mean values for one of the eighteen physical measurements. In other words, it will be observed that the series of means of each table is so arranged as to represent the age-to-age change in the mean magnitude of a single physical dimension.

By transposing each series of means from tabular to graphic form it is possible to obtain a much clearer portrayal of mean growth from age to age. This is done in Figures 1 to 5. These graphs illustrate the mean "course of growth" or "rhythm of growth" for each of the eighteen anthropometric measurements.

The last four of the eighteen graphs are semischematic below six years of age. The advisability of this construction follows from the fact that curves drawn to the mean values at each three month interval would unnecessarily confuse the major characteristics of the trend lines.

COMPARISON OF CENTRAL TENDENCY CURVES

A comparison of the eighteen obtained mean trends is the next logical step in analysis. Three methods are available for this purpose: (1) inspection of graphs, (2) superimposition of curves, and (3) curve fitting.

Inspection of Graphs

The method of inspection will be found to confirm the following observations:

1. The trend lines for stature, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse diameter of thorax, antero-posterior diameter of thorax, thoracic circumference, and body weight (Figures 1 and 2) are roughly similar in form.

> "In each case there is a period of rapid growth in infancy. Succeeding this is an interval of regular but slow increment in early and middle childhood. This is followed by a period of rapid parapuberal increase. And the progression is completed by a final period of slow increment characteristic of adolescence and . . . . of early maturity." (21, p. 185)

This four-phased type of alternate quickening and slowing of

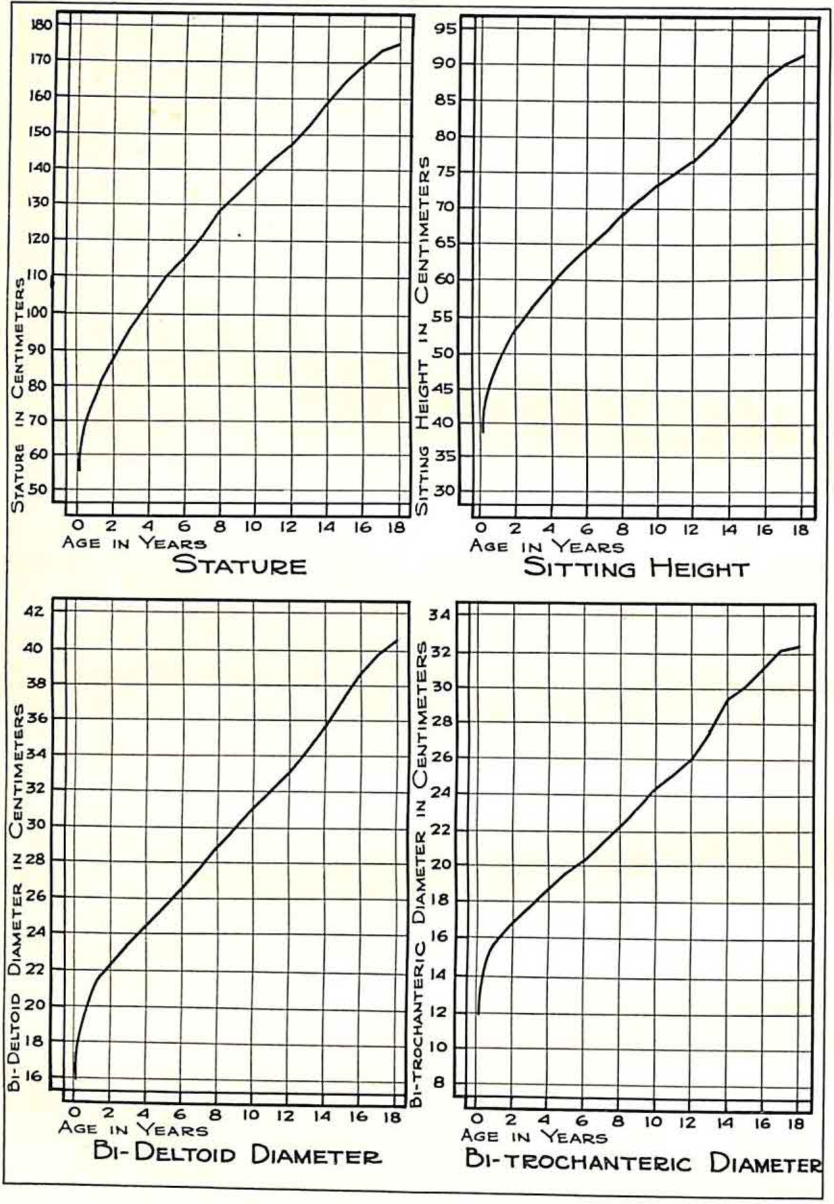


Figure 1. Curves of central tendency illustrating the mean "course of growth" for Iowa City white males in stature, sitting height, bi-deltoid diameter, and bi-trochanteric diameter are given. Each trend is drawn to one of the four series of means presented in Tables 1 to 4.

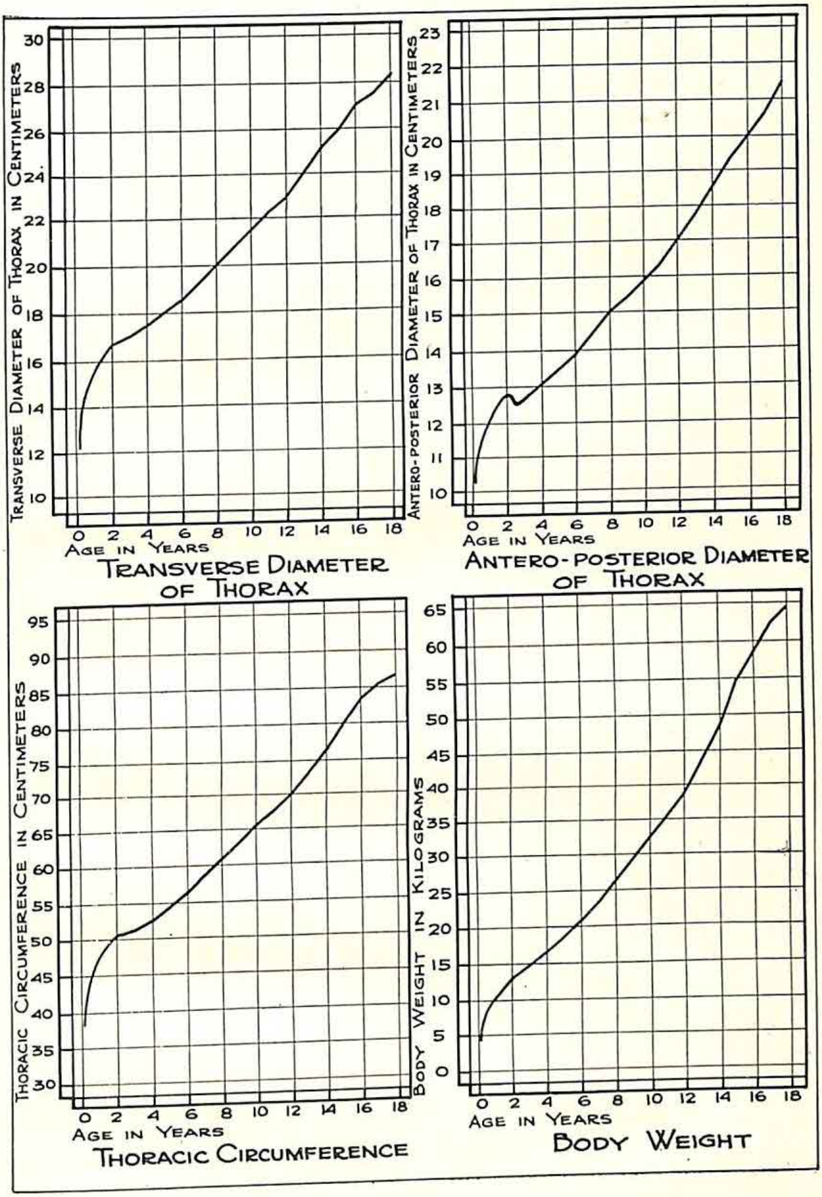


Figure 2. Mean "course of growth" curves for Iowa City white males are shown. The values on which the trend for transverse diameter of thorax is based are given in Table 5. The three successive tables (6, 7, 8) show the means to which the trends for antero-posterior diameter of thorax, thoracic circumference, and body weight are drawn.

growth has been designated by Scammon as the "general type" of postnatal growth in bodily dimensions.

2. On more refined examination, Figures 1 and 2 reveal certain distinctive differences in the forms of the curves they portray. In particular, they support the finding of Baldwin that during childhood "growth curves in weight tend toward concavity; those in height toward convexity." (1, p. 93) For the period between two years and twelve years the curves show transition from a convex form, represented by stature and sitting height, through a more or less linear trend shown for bi-deltoid and bi-trochanteric diameter, to a concave form, definite for thoracic circumference and body weight.

3. The curve for bi-trochanteric diameter (Figure 1) shows a marked ascent between the thirteenth and fourteenth years. This is considered to suggest that there is a rapid mean increase during this year in the pelvic breadth of white males.

The trend for antero-posterior diameter of thorax (Figure 2) is characterized by a depression between the second and third years. This finding has bearing on the change in contour of the chest which takes place during the first three or four years of life. It is known that

> ". . . . in early infancy the thorax of man is narrow and deep like that of the anthropoid apes and remotely resembles the condition found in lower mammals; but when the erect posture is assumed the thorax expands more transversely than in depth. . . ." (11, p. 247)

Figure 2 appears to indicate that the thorax not only "expands more transversely than in depth" but that between the second and third years there is a decided mean decrease in thoracic depth.

4. The curves for maximum head length and breadth (Figure 3) show two major phases—a phase of extremely rapid growth below two years of age and a markedly slower growth phase extending between two and eighteen years. Dimensions having this form of mean curve classify under what Scammon has termed the "neural type" of postnatal growth. (21, p. 187-188)

5. The mean trends for bi-condylar diameter of left femur and humerus (Figure 3) are similar in general form and represent a third distinct type of curve. In each instance the "rhythm of growth" may be regarded as consisting of three convex cycles. The first of these cycles extends from birth to six years, the second from six to eleven years, and the third from eleven to eighteen years.

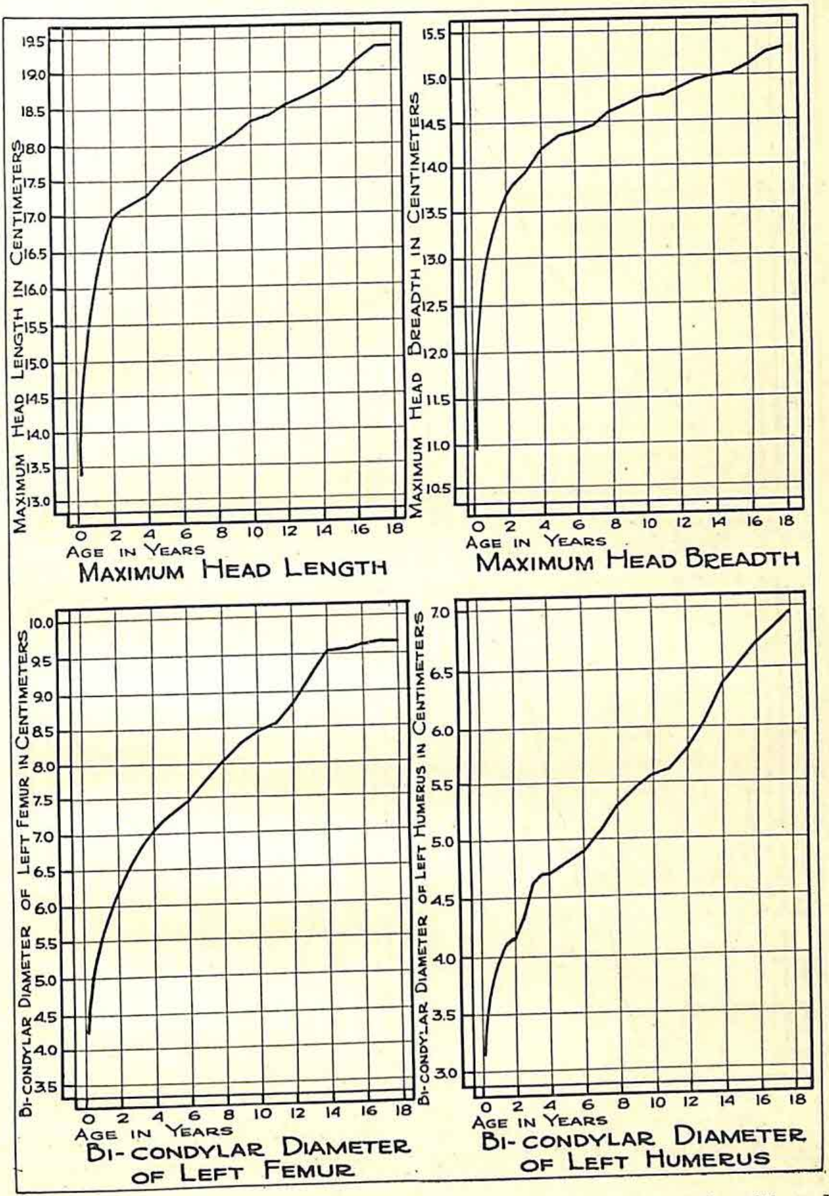
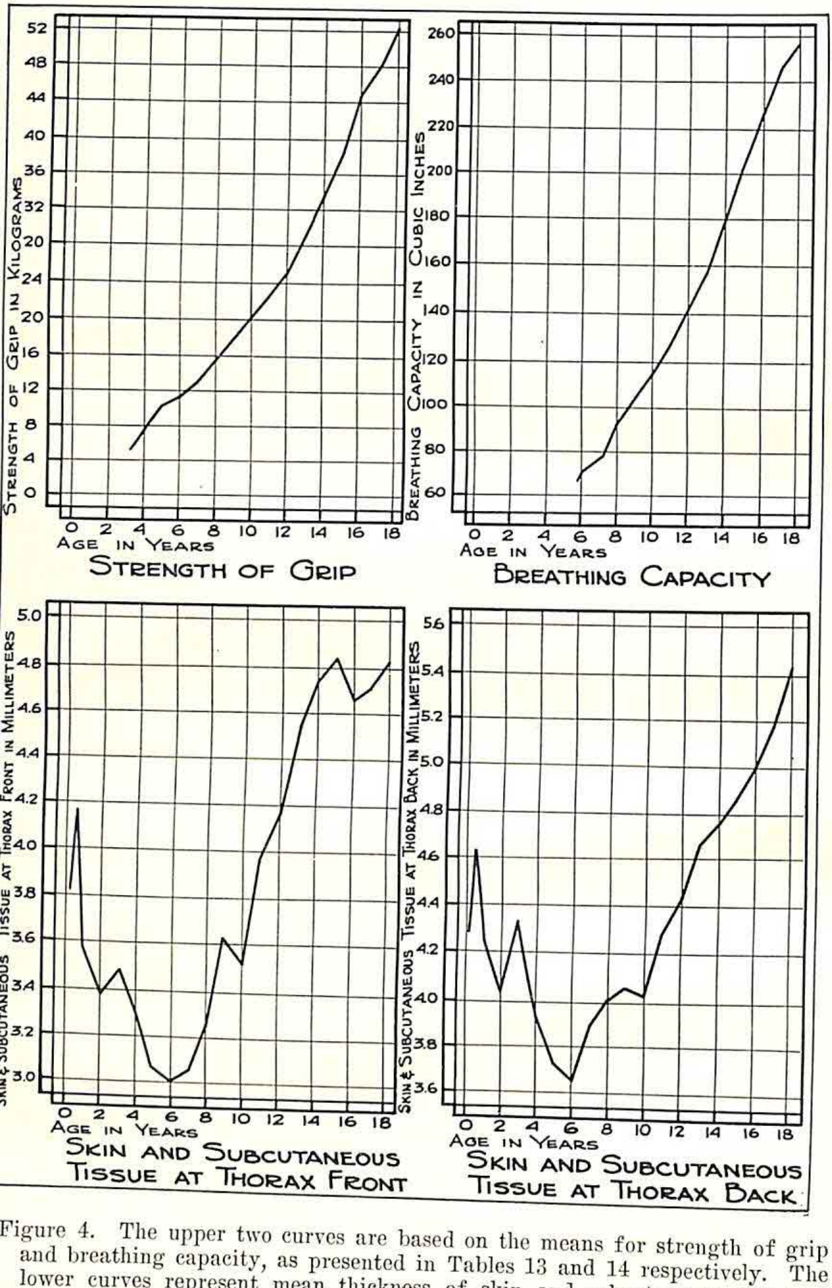


Figure 3. Central tendency plots for maximum head length and breadth and for bi-condylar diameter of left femur and left humerus are drawn to the four series of means given in Tables 9 to 12, inclusive. Measurements were taken of Iowa City white males.



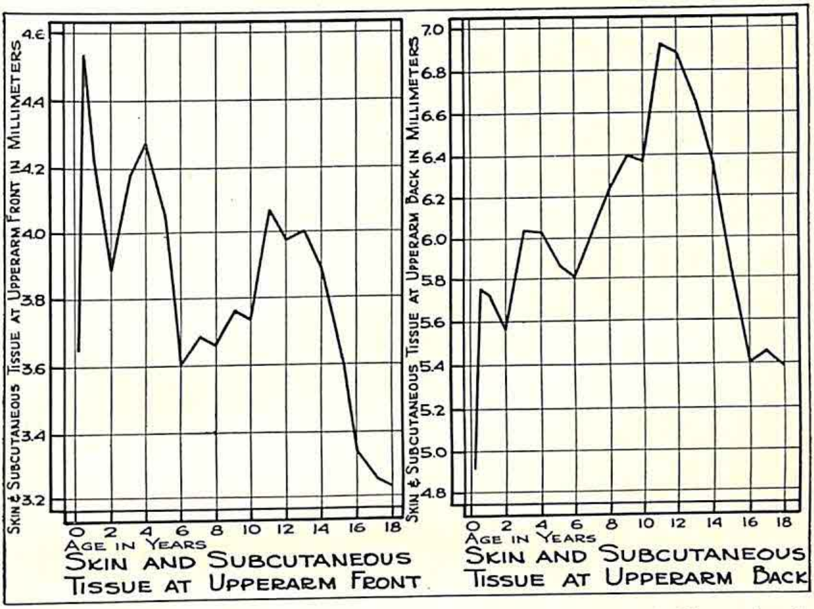
STRENGTH OF GRIP

BREATHING CAPACITY

SKIN AND SUBCUTANEOUS TISSUE AT THORAX FRONT

SKIN AND SUBCUTANEOUS TISSUE AT THORAX BACK

Figure 4. The upper two curves are based on the means for strength of grip and breathing capacity, as presented in Tables 13 and 14 respectively. The lower curves represent mean thickness of skin and subcutaneous tissue at thorax front and thorax back. These trends are based on Tables 15 and 16 but are semi-schematic below six years The four curves portray mean growth for Iowa City white males.



SKIN AND SUBCUTANEOUS TISSUE AT UPPERARM FRONT

SKIN AND SUBCUTANEOUS TISSUE AT UPPERARM BACK

Figure 5. Mean magnitude curves are shown for thickness of skin and subcutaneous tissue at upperarm front and upperarm back on Iowa City white males. Beyond six years each curve is plotted to the means given in Tables 17 and 18. Below six years semischematic representation is made of the major characteristics of each observed point-to-point trend.

The curve for the bi-condylar diameter of the left humerus shows, in addition to its three major cycles, two minor fluctuations. Both of these fluctuations occur between the first and the fourth years; one, a depression, reaches its minimum early in the third year while the other, a peak, attains its maximum around the first quarter of the fourth year. Further research is needed before a conclusive statement can be made as to whether these fluctuations have biological reality or are to be explained as a function of the particular sample of values used in this study.

6. The graphs for strength of grip and breathing capacity (Figure 4) show that the mean "course of growth" for these measures is of a three phase type. There is relatively slow and constant growth below twelve years, a period of rapid increase between about twelve and sixteen years, and a phase above sixteen years indicating a decline in growth rate.

7. The curves for the four measurements of skin and subcutaneous tissue (Figures 4 and 5) are very similar in form below eleven years of age, but above this age show extreme divergence

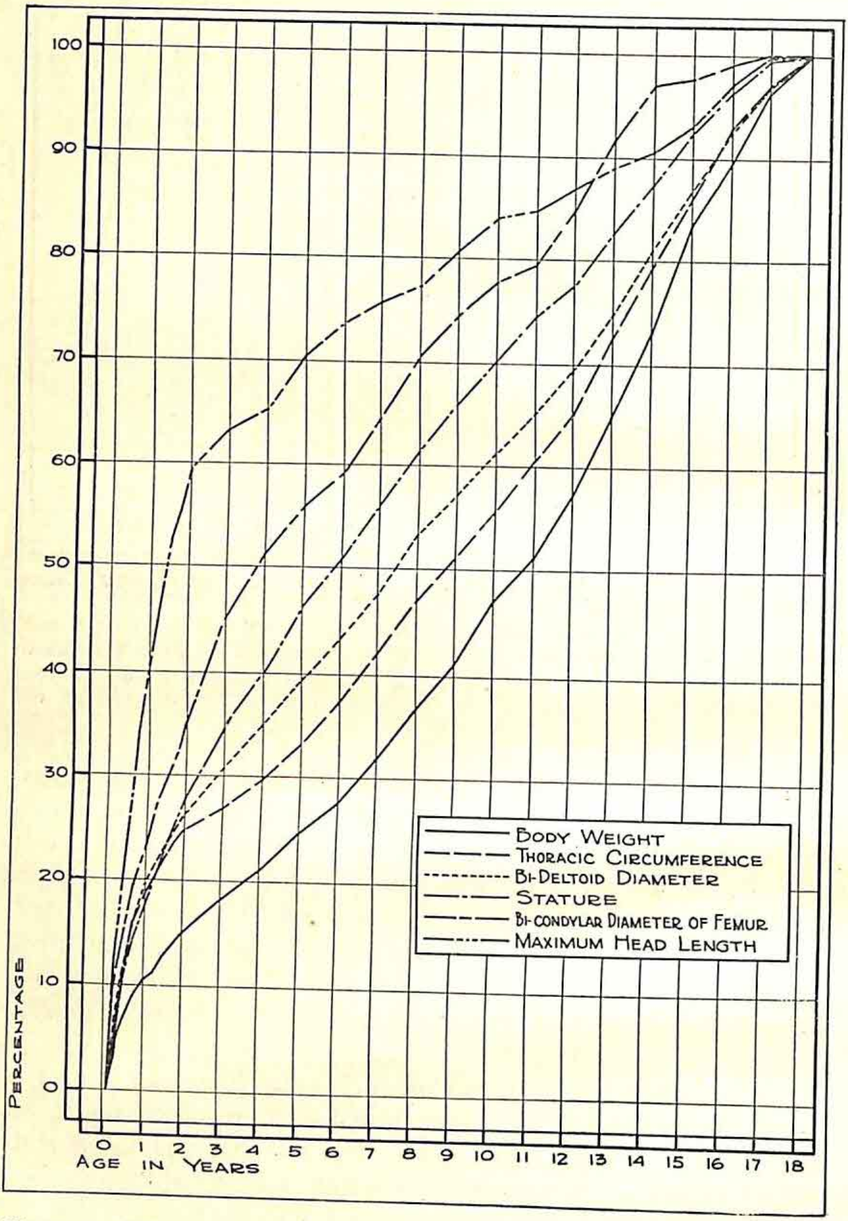


Figure 6. Six superimposed curves illustrate the mean growth of Iowa City white males in maximum head length, bi-condylar diameter of left femur, stature, bi-deltoid diameter, thoracic circumference, and body weight. The curves have a common ordinate scale since the means for each measurement were plotted after being expressed as per cents of total mean gain between one and one-half months and eighteen years.

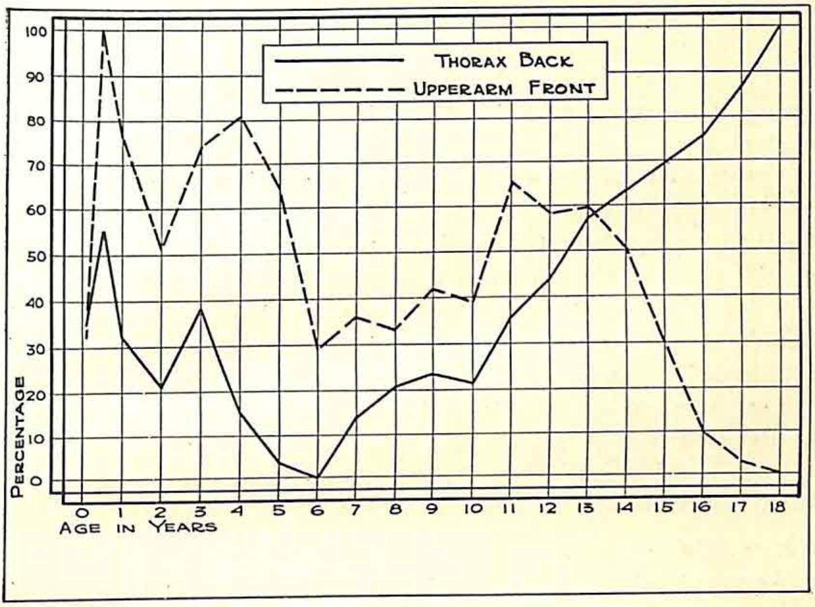


Figure 7. Superimposed "course of growth" trends for thickness of skin and subcutaneous tissue at thorax back and at upperarm front are given. Since the maximum and minimum mean magnitudes for the two measurements are not identical, the absolute ordinate scale for each measurement is replaced by a percentage ordinate scale Observations were made on Iowa City white males.

in type. The most striking features of similarity are minima at ages two and six and maxima at about six months and between the third and fourth years. The four curves are also consistent in showing a slight fall from the ninth to the tenth years and a rise from the tenth to the eleventh years. From the eleventh year forward the curves for the two thorax measurements ascend while the curves for the two upperarm measurements descend.

Superimposition of Curves

The second method of comparison, that of superimposing the mean curves, is employed for two reasons: (1) It furnishes the reader with a medium for rapidly checking many of the findings arrived at by the method of inspection. (2) It serves to give point to these findings.

Since the ordinate scales of the graphs are of diverse magnitudes, it is not possible to superimpose the curves directly. However, several curves may be readily and accurately plotted on a single graph if the curves are first reduced to a percentage basis. Such a procedure is equivalent to substituting a single common scale for each absolute ordinate scale. Figures 6 and 7 afford two composite graphs constructed following the reduction of the curves to a percentage basis.

Figure 6 gives four curves of the "general" type and one each of the "neural" and "three cycle" types. The four general type curves have been selected to illustrate the transition found for the second phase of the curves of this type. It will be noted that for the years between two and twelve stature shows a convex trend, bi-deltoid diameter a more or less linear trend, while the trends for thoracic circumference and body weight are concave.

The mean curves for skin and subcutaneous tissue measurement at the thorax back and at the upperarm front are presented in Figure 7. The similarity of these curves below eleven years and their divergence above this age are strikingly apparent.

Curve Fitting

As previously stated, the third method of approach to a comparison of the mean growth trends for the various dimensions is that of curve fitting. This method involves mathematically graduating the observed mean values for a given measurement and then comparing the derived algebraic equations. For those who have some knowledge of the equations of common curves, the following quotation holds true:

> "Analytic expressions have the great advantage of brevity. They put, in a few symbols, relationships which otherwise must be presented in extensive tables or in elaborate graphic form." (19, p. 23)

Empirical equations for the mean curves of six physical measurements on Iowa City white males are given below:

Breathing capacity $= 37.0\,e^{.11x}$

Maximum head breath $= 13.2\,x^{.049} - 1.1\,e^{-2.1x}$

Thoracic circumference $= 48.805 - 15.1\,e^{-1.96x} + .3397x + .1731x^2 - .003983x^3$

Body weight $= 13.368 - 9.8\,e^{-1.2x} - .1325x + .2504x^2 - .004413x^3$

Stature $= 66.255 - 16\,e^{-2.7x} + 12.7537x - 1.1260x^2 + .075849x^3 - .001891x^4$

Bi-condylar diameter of left femur $= 4.861 + .8362x - .1060x^2 + .007984x^3 - .000215x^4$

"x" in every instance is "age in years."

The first two equations were derived by the method of averages (13) and the following four by the method of least squares (22).

Table 19 gives the observed and the estimated mean values for each measurement at annual intervals from one to eighteen years inclusive. "Difference" columns show the values of the estimated mean minus the observed mean at each age. An indication of the "goodness of fit" is obtained by finding the mean of each difference column, disregarding the sign. These mean differences read 0.03 cm. for head breadth, 0.07 cm. for bi-condylar diameter of left femur, 0.35 cm. for thoracic circumference, 0.67 cm. for stature, 0.64 kg. for body weight, and 5.8 cu. in. for breathing capacity. Figure 8 permits a comparison of the graphic form of each derived equation with the mean curve plots (drawn to observed values) shown in Figures 1 to 4.

The present position of the writer is that the method of curve fitting provides an interesting approach to a comparison of mean growth trends but that, with reference to many bodily dimensions on the human male between birth and early maturity, it is an involved attack which yields but crude results. In this connection the reader is referred to Table 19. It will be noted that in every instance the estimated values "fit" the observed values least well at around eleven and twelve years of age. That is to say, curve fitting "smoothes" the mean values most at those sections of the curve where there is a change from one phase to another, thus tending to eradicate the maxima and minima which give the curve its distinctive form.

Attention is also called to the fact that bi-condylar diameter of the femur, a distinctly three cycle curve, is fit with a two cycle (fourth degree) equation. While the form of the curve is entirely changed (See Figures 6 and 8), the fit appears sufficiently adequate for purposes of prediction, interpolation, and other such reasonable uses. (See Table 19.)

More will be said in Chapter III with reference to the limitations of the use of algebraic expressions for the purpose of studying the postnatal human growth curve for various bodily dimensions. The words "postnatal" and "human" are both important here. Brody (2) finds that the growth trends for many domestic animals are of a simple two phase form. Equations derived for such trends, of course, would not eradicate major maxima or minima. Scammon and Calkins (20), likewise, find prenatal human growth to show a two phase "rhythm." It should be clearly understood that the writer's criticisms apply mainly to trends having not less than three

Table 19

Observed and Estimated Mean Values, at Annual Intervals Between One and Eighteen Years, for Each of Six Anthropometric Measurements

Mean Age	Maximum Head Breadth (Centimeters)			Bi-Condylar Diameter of Left Femur (Centimeters)			Stature (Centimeters)			Thoracic Circumference (Centimeters)			Body Weight (Kilograms)			Breathing Capacity (Cubic Inches)		
	Observed	Estimated	Difference	Observed	Estimated	Difference	Observed	Estimated	Difference	Observed	Estimated	Difference	Observed	Estimated	Difference	Observed	Estimated	Difference
1	13.06	13.06		5.51	5.60	+.09	76.5	76.9	+ .4	47.2	47.2		10.5	10.5				
2	13.70	13.65	−.05	6.14	6.17	+.03	88.5	87.8	− .7	50.2	49.9	−.3	13.2	13.2				
3	13.93	13.93		6.69	6.61	−.08	96.2	96.3	+ .1	51.1	51.2	+.1	15.2	14.8	− .4			
4	14.20	14.13	−.07	7.04	6.97	−.07	103.3	104.6	+1.3	52.7	52.7		17.1	16.5	− .6			
5	14.35	14.28	−.07	7.28	7.26	−.02	110.1	110.2	+ .1	54.4	54.4		19.0	18.4	− .6			
6	14.40	14.40		7.46	7.51	+.05	115.7	116.2	+ .5	56.3	56.2	−.1	20.9	20.6	− .3	70.2	71.6	+ 1.4
7	14.48	14.52	+.04	7.75	7.74	−.01	121.9	121.8	− .1	58.7	58.3	−.4	23.5	23.2	− .3	78.5	79.9	+ 1.4
8	14.62	14.62		8.08	7.97	−.11	128.1	127.3	− .8	61.0	60.6	−.4	26.3	26.1	− .2	92.5	89.1	− 3.4
9	14.70	14.70		8.28	8.21	−.07	133.7	132.7	−1.0	63.1	63.0	−.1	29.0	29.2	+ .2	103.5	99.5	− 4.0
10	14.77	14.77		8.48	8.46	−.02	138.9	138.1	− .8	65.7	65.6	−.1	32.5	32.7	+ .2	115.5	111.1	− 4.4
11	14.79	14.84	+.05	8.56	8.71	+.15	143.2	143.6	+ .4	67.6	68.2	+.6	35.3	36.3	+1.0	127.5	121.6	− 5.9
12	14.85	14.90	+.05	8.85	8.97	+.12	147.8	149.0	+1.2	70.0	70.9	+.9	38.7	40.2	+1.5	141.9	138.5	− 3.4
13	14.95	14.96	+.01	9.23	9.22	−.01	153.3	154.4	+1.1	73.3	73.7	+.4	43.6	44.3	+ .7	157.4	154.6	− 2.8
14	14.99	15.02	+.03	9.52	9.44	−.08	159.4	159.6	+ .2	76.8	76.6	−.2	48.6	48.5	− .1	179.9	172.5	− 7.4

15	15.09	15.07	−.02	9.57	9.61	+.04	165.2	164.5	− .7	80.0	79.4	−.6	54.9	52.8	−2.1	203.8	192.6	−11.2
16	15.12	15.12		9.63	9.71	+.08	169.7	168.8	− .9	83.2	82.3	−.9	58.4	57.3	−1.1	227.5	214.9	−12.6
17	15.24	15.17	−.07	9.68	9.71	+.03	173.5	172.4	−1.1	85.4	85.1	−.3	62.4	61.8	− .6	247.5	240.0	− 7.5
18	15.28	15.21	−.07	9.68	9.56	−.12	174.2	174.9	+ .7	86.9	87.8	+.9	64.7	66.4	+1.7	257.2	267.9	+10.7
Mean Difference*			.03			.07			.67			.35			.64			5.8

*Disregarding sign.

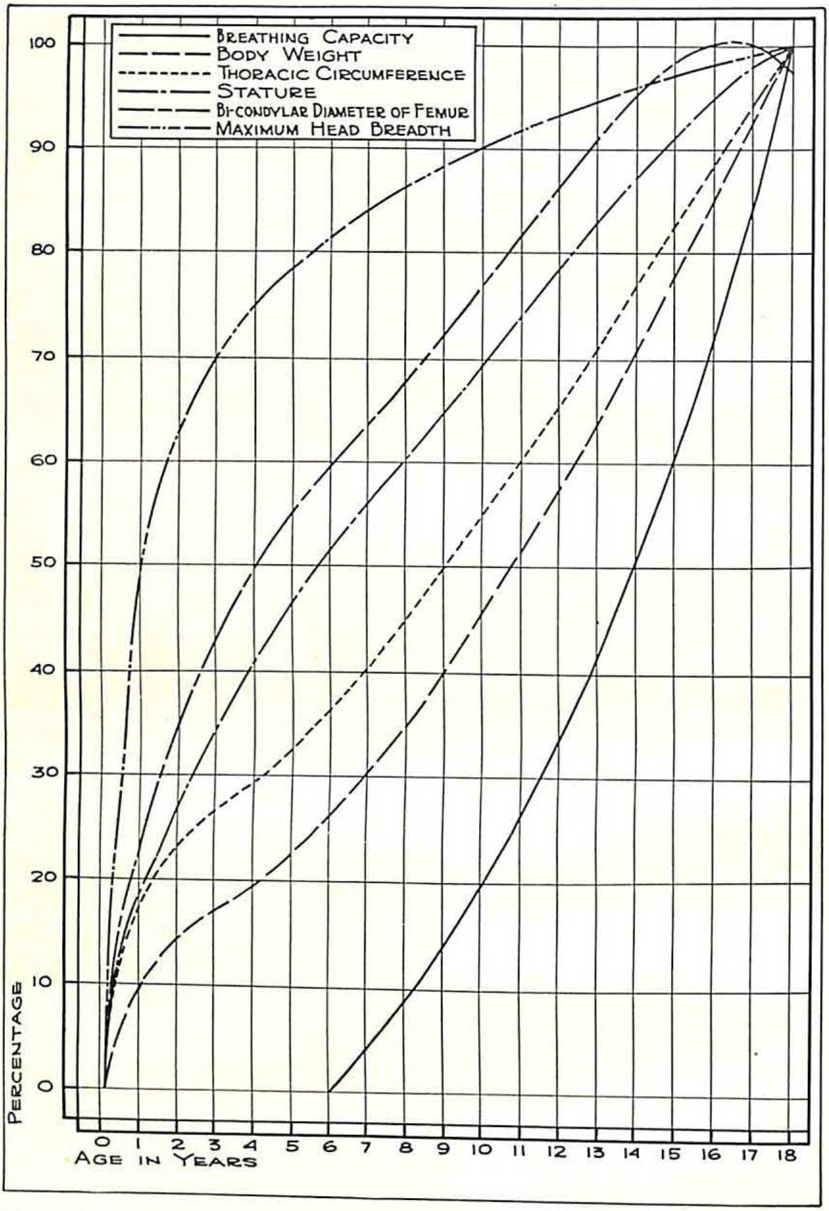


Figure 8. The above is a series of six curves given by empirical equations "fit" to observed means for Iowa City white males on the following measurements: maximum head breadth, bi-condylar diameter of left femur, stature, thoracic circumference, body weight, and breathing capacity. The curves are converted from absolute to percentage units in order to facilitate presentation on a single graph. Note that the curve for breathing capacity extends over a twelve year, rather than an eighteen year, age period.

phases, and that the criticisms are considered increasingly pertinent as the curves become more complex.

MEAN GROWTH CONTRASTS

The analysis of the data with respect to central tendency will be concluded with a brief presentation of a number of contrasts on mean growth. These contrasts are such as may be observed when a series of mean values for a given measurement are expressed with reference to one or the other of the extreme mean magnitudes for the series.

Study of each measurement after expressing the mean values for selected ages as percentages of the mean magnitude attained at the eighteenth year reveals the following contrasts:

1. At one year of age Iowa City white males most nearly approach their adult status in head dimensions and are least developed in body weight. The bi-condylar diameters of femur and humerus are farther advanced toward their final magnitude than are the bi-deltoid and bi-trochanteric diameters. The obtained percentages for this age, arranged in descending order, are 71 for head breadth, 69 for head length, 57 for bi-condylar diameter of femur, 56 for bi-condylar diameter of humerus, 56 for depth of thorax, 55 for width of thorax, 54 for thoracic circumference, 53 for sitting height, 51 for bi-deltoid diameter, 49 for bi-trochanteric diameter, 44 for stature, and 16 for body weight.

2. At two years of age the percentage development of weight is 20, of stature 50, of bi-condylar diameter of humerus 60, and of maximum head breadth 90. A selection of equally striking differences at eight years of age shows that in strength of grip, breathing capacity, body weight, thoracic circumference, bi-condylar diameter of femur, and maximum head length the white males used in this study have attained 30, 36, 41, 70, 83, and 93 per cent, respectively, of their mean magnitudes for these measurements at eighteen years.

3. The percentage values for stature at ages three, ten, and fourteen years are 55, 80, and 92. Corresponding values for sitting height are 62, 80, and 90 per cent. The reversal in the relation of the percentages from three to fourteen years is indicative of the fact that leg length is growing at a faster pace than sitting height during these years. Figures for derived leg length, obtained by deducting sitting height means from the means for stature, show that between six weeks of age (the age corresponding to the earliest

mean value) and fourteen years of age there is a mean increase in leg length of 350 per cent. The increase in sitting height over this period is 115 per cent. It should be noted that, while leg length (derived) is found to increase more rapidly than sitting height until the fourteenth year, at no age does the mean value for leg length exceed or equal that for sitting height.

Additional contrasts were discovered by expressing mean values for certain ages as percentages of the mean value at the lower end-point of the age period, that is, the mean at six weeks after birth. These contrasts are given below:

1. The mean values for twelve anthropometric measurements on Iowa City white males at six weeks of age are increased by 100 per cent at the following ages: six months for weight, six years for stature, nine years for bi-trochanteric diameter, ten years for bi-condylar diameter of femur, eleven years for bi-deltoid diameter, twelve years for sitting height, thirteen years for thoracic width, fourteen years for thoracic circumference and bi-condylar diameter of humerus, seventeen years for depth of thorax, and not at all for head length and breadth.

2. Between six weeks and the eighteenth year, that is, approximately from birth to early maturity, the percentage increase in head breadth is 40, in head length 44, in thorax depth 110, in bi-condylar diameter of humerus 123, in bi-condylar diameter of femur and thoracic circumference 128, in width of thorax 135, in sitting height 139, in bi-deltoid diameter 156, in bi-trochanteric diameter 171, in stature 214, and in weight 1,429.

3. The percentage increase for head length is 26 at two years, 33 at six years, 37 at ten years, 40 at fourteen years, and 44 at eighteen years. Corresponding percentages for head breadth are 26, 32, 35, 37, and 40, respectively. The gradual divergence corroborates the growth principle that white peoples show a trend away from brachycephalism with increasing age.

4. Between six years and eighteen years breathing capacity increases 267 per cent and strength of grip 359 per cent. (The point of reference is necessarily taken at six years since breathing capacity is not secured at younger ages.)

The lay reader is cautioned to differentiate clearly the two types of analysis made in this section. They are not two approaches to the same facts. The one approach indicates that the average Iowa City white male doubles his stature between birth and six years of age. The other approach shows that he has attained half his adult stature at about two years of age. Obviously, these are not two ways of expressing the same finding.

ABSOLUTE VARIABILITY

Thus far analysis has been restricted to average growth in the group. It is now necessary to recognize (1) that mean values describe but one aspect of the data included in our distributions, and (2) that in an attempt to secure a sound understanding of growth, it is of no less importance to scrutinize these distributions with respect to dispersion about the mean.

Inspection of the range column in Tables 1 to 18 reveals the following facts in regard to individual differences in bodily growth:

1. The boys who at the age of one year rank at the upper end of the distributions for head breadth have wider heads than have the boys at the lower end of the distribution for the eighteenth year. Similarly, the boys with the shortest heads at eighteen years of age are exceeded in this dimension by the boys with the longest heads at the age of fifteen months.
2. There are Iowa City white males who at three years of age have a greater bi-condylar diameter of the humerus than is observed for other white males of Iowa City who are thirteen years of age. Likewise, our data show that there are boys of eighteen years who have not attained a bi-condylar diameter of the femur equal to that found to characterize some boys at eight years of age.
3. The boy with the smallest chest girth at eighteen years does not exceed the boy with the maximum chest girth at seven years. The boy with the minimum chest girth at seven years is exceeded by the boy with the maximum chest girth at six months.
4. The lightest individual at eighteen years is no heavier than the heaviest individual at eight years. The lightest individual at eight years is hardly as heavy as the heaviest individual of two years.

Similar observations might be itemized at great length. Such a procedure, however, is inadvisable since more adequate measures than the range (which confines attention to the most extreme values only) are available for describing variability.

The most commonly used measure of absolute "spread" or "scatter" is the standard deviation. The common usage given this measure follows from its reliability and the fact that it lends itself to algebraic treatment. The measure is defined as the square root of the mean of the squares of the differences between the individual cases and the average value. Standard deviation values for each of the 529 distributions will be found in Tables 1 to 18.

If the entire 529 distributions each represented a normal frequency curve, the interpretation of the standard deviation values would be straightforward. In this event every value would have the same meaning and the standard deviation would furnish "in summary and comprehensible form" a complete description of the variability of each distribution. One standard deviation added to and subtracted from the mean would give the limits within which 68.26 per cent of the measurement observations in a distribution fell; seven-tenths (.6745) of a standard deviation laid off in the plus and minus directions from the mean would delimit the middle 50 per cent of the observations; the mean plus and minus three standard deviations would provide limits approximately equal to the range.

As a matter of fact, however, interpretation is considerably more complex. Of the 529 distributions probably a considerable number are significantly non-normal. In this connection the following tabulation of skewness and kurtosis values for distributions of thoracic circumference is pertinent. The formulae used in computing these values are taken from Pearl (17, p. 277-279).

Age Group									
Years	Months	Days		Years	Months	Days	Cases	Skewness	Kurtosis
		0	to		5	30	143	+.133 ± .102*	+ .146 ± .410*
	6	0	to		11	30	307	+.043 ± .070	− .362 ± .280
1	0	0	to	1	5	30	240	+.054 ± .079	− .374 ± .316
1	6	0	to	1	11	30	196	+.229 ± .087	− .426 ± .350
2	0	0	to	2	5	30	169	+.189 ± .094	− .074 ± .377
2	6	0	to	2	11	30	178	−.064 ± .092	+ .063 ± .367
3	0	0	to	3	5	30	178	−.035 ± .092	− .131 ± .367
3	6	0	to	3	11	30	217	−.295 ± .083	− .574 ± .333
4	0	0	to	4	5	30	225	−.121 ± .082	− .393 ± .327
4	6	0	to	4	11	30	247	+.086 ± .078	− .199 ± .312
5	0	0	to	5	5	30	315	+.170 ± .069	+1.495 ± .276
5	6	0	to	5	11	30	324	+.208 ± .068	+ .844 ± .272
6	0	0	to	6	5	30	261	+.194 ± .076	+ .265 ± .303
6	6	0	to	7	5	30	510	+.219 ± .054	+ .886 ± .219
7	6	0	to	8	5	30	472	+.241 ± .056	+2.452 ± .226
8	6	0	to	9	5	30	452	+.272 ± .058	+2.632 ± .230
9	6	0	to	10	5	30	362	+.332 ± .064	+2.389 ± .258

* These columns give standard error values, not probable errors.

Age Group							Cases	Skewness	Kurtosis
Years	Months	Days		Years	Months	Days			
10	6	0	to	11	5	30	355	+.345 ± .065*	+2.637 ± .260*
11	6	0	to	12	5	30	317	+.491 ± .069	+3.664 ± .275
12	6	0	to	13	5	30	298	+.439 ± .071	+1.792 ± .284
13	6	0	to	14	5	30	286	+.465 ± .072	+2.883 ± .290
14	6	0	to	15	5	30	316	+.234 ± .069	+ .705 ± .276
15	6	0	to	16	5	30	282	+.098 ± .073	+1.796 ± .292
16	6	0	to	17	5	30	235	+.108 ± .080	+1.693 ± .320
17	6	0	to	18	5	30	180	+.161 ± .091	+1.804 ± .365

* These columns give standard error values, not probable errors.

With reference to skewness it will be noted that below seven years of age the distributions are not significantly asymmetrical but that between seven and fifteen years they are significantly skewed in the positive direction. Maximum positive skewness is reached at twelve years. At this age the skewness value is seven times its standard error. As regards kurtosis, the distributions are mesokurtic below seven years and leptokurtic between seven and eighteen years. Maximum leptokurtosis is reached at twelve years, being over thirteen times its standard error. Since the normal frequency curve is symmetrical and mesokurtic, we conclude that the distributions for thoracic circumference are significantly non-normal at least between the seventh and the fifteenth years. Another measurement where distributions for certain age intervals have long been known to show considerable departure from normality is body weight.

It is in view of such considerations as we have just discussed that Tables 1 to 18 inclusive carry a column giving the range. For meaningful interpretation of absolute variability the range should be consulted in conjunction with the standard deviation value.

RELATIVE VARIABILITY

Following the interpretation of dispersion within a given distribution consideration is given to a comparison of different distributions in regard to this characteristic. Before it is possible to compare the variability of any one of the distributions with that of any or all of the other 528 distributions, it is necessary that the standard deviation values be expressed as pure numbers. Little elaboration is needed to make this evident. Obviously the standard deviation for the seven year distribution of bi-trochanteric diameter cannot be directly compared with the standard deviation values of the body weight or breathing capacity distributions for the same age since these measurements are given in different units—one in centimeters, another in kilograms, and the third in cubic inches. It is also true that the standard deviation of the seven year distribution for bi-trochanteric diameter cannot be directly compared with the standard deviation of the fourteen year distribution for the same dimension, the reason being that the standard deviation values are measured around unlike central tendencies. Such comparisons, however, may be rendered legitimate and meaningful if each standard deviation is expressed as a percentage of the mean around which it is measured. That is, when absolute variability values are divided by their corresponding means and multiplied by one hundred, a relative measure is obtained which is a pure number. This number is termed the coefficient of variation.

Coefficient of variation values are given in Tables 1 to 18 inclusive for each distribution. Cursory inspection of these values suggests that variability differs not only from measurement to measurement but also from age to age for the same measurement. The findings will be summarized in the following: (1) measurement to measurement differences, and (2) age to age differences.

For the purpose of making a general comparison between measurements, a single coefficient has been obtained for each measurement. Each summary coefficient represents the mean of the relative variation values for all distributions on a measurement except that one covering the age interval from birth to three months. (Exclusion of the value for the lowest distribution was considered advisable in view of the small number of observations on which it was based.) The obtained coefficients, arranged in increasing order, are:

Measurement	Coefficient
Maximum head length	3.8
Maximum head breadth	3.9
Stature	3.9
Sitting height	4.1
Thoracic circumference	5.5
Transverse diameter of thorax	5.8
Bi-deltoid diameter	5.8
Bi-condylar diameter of left femur	5.9
Bi-condylar diameter of left humerus	6.5
Bi-trochanteric diameter	6.6

Measurement	Coefficient
Antero-posterior diameter of thorax	6.9
Body weight	13.1
Breathing capacity	17.5
Strength of grip	21.7
Skin and subcutaneous tissue at upperarm back	21.8
Skin and subcutaneous tissue at thorax back	23.7
Skin and subcutaneous tissue at upperarm front	27.6
Skin and subcutaneous tissue at thorax front	28.6

The comparative findings which may be drawn from the above tabulation are numerous. A sampling of them are listed below:

1. Head length is the least variable of the eighteen measurements. It is 97 per cent as variable as stature, 69 per cent as variable as thoracic circumference, 58 per cent as variable as bi-trochanteric diameter, 29 per cent as variable as body weight, and 13 per cent as variable as skin and subcutaneous tissue at thorax front.

2. Head breadth is more variable than head length. Harris (10) reports the same finding for newborn infants of six nationalities, using it as an illustration of the usefulness of the coefficient of variation. Since his discussion has double aspect value—lending support to the above finding on the one hand and elucidating the value of the coefficient of variation on the other—it appears not amiss to quote him at this juncture.

> "\. . . . the length or occipito-frontal diameter . . . . of the head of the newborn infant has a higher standard deviation than the breadth (or biparietal diameter). . . . . the average occipito-frontal diameter is greater than the biparietal in all nationalities studied. Since the occipito-frontal dimension is larger, it is reasonable to expect that it will have a larger absolute variability (standard deviation). When we correct for the average magnitudes of the two dimensions by expressing the standard deviations as percentages of their means (that is, as coefficients of variation), it appears . . . . that in general the variability of the breadth of the head is greater than that of the length." (10, p. 26; 28)

3. Stature is equal in variability to head breadth and is 95 per cent as variable as sitting height, 60 per cent as variable as bi-condylar diameter of humerus, and 18 per cent as variable as strength of grip.

4. Antero-posterior diameter of the thorax is the most variable of the three thorax measurements; thoracic circumference is the least variable. Thoracic circumference is 95 per cent as variable

as the transverse diameter and 80 per cent as variable as the antero-posterior diameter.

5. Variability in breathing capacity is over three times as great as variability in thoracic circumference. The same relationship holds between body weight and stature.

6. Bi-trochanteric diameter is more variable than bi-deltoid diameter. Stated conversely, bi-deltoid diameter is 88 per cent as variable as bi-trochanteric diameter.

Age-to-age differences in relative variability may best be summarized by a tabulation of the coefficients obtained for four distributions which appear representative of various portions of the age period under consideration. The four distributions selected are those having as age mid-points four and one-half months, five and one-fourth years, fourteen years, and eighteen years.

	Coefficient of Variation			
Measurement	4½ Months	5¼ Years	14 Years	18 Years
Maximum head length	4.9	3.6	3.2	3.4
Maximum head breadth	5.6	3.7	3.5	3.2
Stature	4.4	3.7	5.4	3.6
Sitting height	4.8	3.9	5.6	4.2
Thoracic circumference	5.2	4.2	8.8	7.0
Transverse diameter of thorax	6.4	5.1	8.3	6.1
Bi-deltoid diameter	8.6	4.5	7.8	5.5
Bi-condylar diameter of femur	7.6	4.0	6.8	5.9
Bi-condylar diameter of humerus	7.2	5.6	7.1	6.2
Bi-trochanteric diameter	8.0	4.9	9.1	6.6
Antero-posterior diameter of thorax	7.2	5.8	9.2	8.0
Body weight	13.0	10.3	20.4	14.1
Breathing capacity			21.0	15.9
Strength of grip		20.5	21.6	16.6
Skin and subcutaneous tissue at upperarm back	16.3	18.3	29.1	32.7
Skin and subcutaneous tissue at thorax back	20.6	20.5	27.8	30.7
Skin and subcutaneous tissue at upperarm front	20.4	20.4	34.8	41.7
Skin and subcutaneous tissue at thorax front	24.9	23.7	37.9	35.0

The above tabulation is considered to epitomize the following findings:

1. Iowa City white males differ more during the first year of life than during the childhood years with respect to head length,

head breadth, stature, sitting height, thoracic circumference, transverse diameter of the thorax, bi-deltoid diameter, bi-condylar diameter of the femur and humerus, bi-trochanteric diameter, antero-posterior diameter of the thorax, and body weight.

2. Iowa City white boys differ more among themselves during the adolescent years than they do during the years preceding or following in stature, sitting height, thoracic circumference, transverse and antero-posterior diameters of the thorax, bi-deltoid and bi-trochanteric diameters, bi-condylar diameter of the femur and humerus, body weight, and breathing capacity. With strength of grip the rise at thirteen to fifteen years is slight, but the fall to eighteen years is decided.

3. The coefficients for head length and breadth show very little change during the years from five to eighteen. There is a slight decrease with age which suggests that the groups tend to become more homogeneous with respect to these measurements.

4. In general, distributions for the measurements of skin and subcutaneous tissue show increasing heterogeneity with age.

CHAPTER III

GROWTH IN THE GROUP: PERCENTAGE RATE

Percentage analysis of mean curves of growth in bodily dimensions may be approached in three ways. To illustrate: one may make such analysis (1) in terms of an initial value, such as the value at birth; (2) with reference to a final magnitude, for example, the magnitude at maturity or at senescence; or (3) in relation to some immediately preceding status, as status at the preceding year or day or instant. Approaches (1) and (2) were used in Chapter II, and a series of findings of the type that accrue from these approaches was presented. In this chapter attention will be concentrated on the third and most valuable approach to the percentage analysis of the "rhythm of growth."

METHODS OF ANALYSIS

Four methods of determining percentage rates of acceleration and retardation at successive ages will be considered. These are (1) Brody's logarithmic method, (2) the method of curve fitting, algebraic differentiation, and calculation of velocity ratios, (3) the graph-tangentmeter-ratio method, and (4) Minot's arithmetic method.

Brody's Logarithmic Method

The logarithmic method of Brody (2) enables one to obtain percentage rate values—amounts of percentage increment or decrement over given units of time—directly by formula. The procedure is economical and reliable. However, the formula is derived from the general equation for a simple exponential curve. Examination of the integral curves presented in Figures 1 to 5 will show that only two of these curves—those for maximum head length and maximum head breadth—approximate the exponential form. Consequently, this method is rejected as not being valid for use in this study.

In fairness to Brody, it is important to add (1) that his formula was derived for obtaining percentage rate curves of weight for certain domestic animals, and (2) that he found it to be inapplicable to an analysis of human growth in body weight and stature over the age period between birth and puberty (3). The method is introduced here primarily because some have used it for the study of percentage rates of physical growth in children.

Method of Curve Fitting, Algebraic Differentiation, and Calculation of Velocity Ratios

The second method listed for consideration involves application of the calculus. In terms of the present investigation, the procedure would consist of graduating the mean values for each measurement, differentiating the derived integral equations, computing instantaneous rates—gains or losses over negligibly small units of time—from the differential equations, and converting the obtained absolute rates into a relative or percentage form. Provided that each derived integral equation accurately fit the series of means it represented, this method would furnish a most precise and complete analysis of percentage growth. It is impossible, however, to satisfy this provision in the case of almost all of the mean curves here under consideration. This was shown in the previous chapter. To recapitulate: empirical equations which "best approximate" the mean curves for the postnatal growth of Iowa City white males in various bodily dimensions were found to "smooth," and in some instances to eradicate, major changes in phase. Since these changes in phase represent changes in rate of growth, they are obviously crucial in the study of the age-to-age trend of percentage increase and decrease. What is needed is a technique for revealing, rather than beclouding, such changes. This method, therefore, is not used.

It will probably have occurred to the reader that the limitations advanced against curve fitting and the use of differential equations would be resolved if the mean curves were broken up into one- or two-phase segments. This is admitted as probably true. In more restricted and refined studies the calculus may be found "invaluable for the analysis of human growth." The purpose of this study, however, is to treat each mean curve as a unit and, perchance, to discover those segments which are worthy of intensive study.

Graph-Tangentmeter-Ratio Method

The writer has termed the third method to be discussed the graph-tangentmeter-ratio method. The term indicates the three steps which constitute the procedure. First, a mean curve plot of the measurement variable to be analyzed is constructed. Secondly, a tangentmeter is applied to the curve and the tangent or slope determined at as many points on the curve as desired. Finally, the tangent values are each reduced to percentage values. This last step consists of the division of each absolute rate (tangent value) by its corresponding mean magnitude and multiplication of each obtained quotient by 100.

The relative instantaneous velocities obtained by this method and by the method of algebraic differentiation are comparable in meaning and theoretically are identical. Practically, each method has its specific usefulness. In the event that an integral equation can be derived which accurately fits the form of the curve being studied, the mathematical method is the more precise; in situations where one cannot obtain a reasonably complex equation which closely approximates the form of the curve, the graphic method is the more precise. The two methods permit an equally complete analysis since the rate may be determined by either tangentmeter or differential equation at innumerable points along the curve.

It follows that the graph-tangentmeter-ratio method is the best suited of the three methods discussed thus far for making an analysis of the mean curves obtained in the present study. Nevertheless, this is not the method employed. There are two major reasons for its rejection. First, it is not as reliable and objective as a mathematical method. Inevitable approximations of the uncontrolled type occur in plotting the mean values, in drawing a smooth freehand curve through the coördinate points, and in determining the tangent values. Secondly, the results obtained are not readily verifiable. Whereas a mathematical method permits the reader to check hastily any reported value he may desire to confirm, this method assumes access to a tangentmeter and necessitates the construction of a graph.

Minot's Arithmetic Method

The fourth method, the one used in this study, is the arithmetic method of Minot. This method was devised in 1891 and apparently was first used to obtain the acceleration curve of weight for guinea pigs. In a 1908 publication (16) Minot describes the procedure for finding the "percentage of advance" during a given interval of time as follows:

> "Take the weight at a given age, and the weight at the next older age for which there are observations . . . then express the daily [quarterly or annual] increase as a percentage of the weight at the beginning of the period." (16, p. 93)

This method avoids the uncontrolled approximations of the graph-tangentmeter-ratio method and "has the advantage of simplicity and rapidity in its practical application." (16, p. 94) Moreover, it keeps the analysis of the observed percentage increments and decrements separate from smoothing or interpolation processes and permits the latter to be shown, if desired, as a supplementary curve.

FORM OF PRESENTATION

Percentage rates of growth, determined by direct application of Minot's arithmetic formula to the means given in Tables 1 to 18, are presented in Tables 20 to 37. Since the means for each measurement (presented in the former tables) were derived from age groups of changing size, it follows that various portions of the series of rate values for any one measurement (given in the latter tables) represent unlike units of time. Below two years, ten and one-half months the rate values are in quarter year terms; between three years, three months and six years, three months they are for semiannual intervals; above seven years they represent the rate of growth per annum. Moreover, there is an interval between two years, ten and one-half months and three years, three months where the rate is for four and one-half months, and an interval between six years, three months and seven years where the rate is for nine months.

Expressed in such diverse terms, the percentage growth of Iowa City white males in a given bodily dimension is unhandy to use either for age-to-age comparison or for visualization of the entire trend. To facilitate these ends, Tables 20 to 37 carry full columns of annual percentage rate. These columns are completed above the sixth to seventh year age interval by multiplying the quarterly rates by four, the semiannual rates by two, and so forth.

The tables include another column of absolute rather than relative rate. This is added since absolute increase and decrease values (that is, amount of gain or loss in centimeters, millimeters, kilograms, or cubic inches) are of interest in themselves, and are necessarily obtained as a by-product in application of Minot's formula.

The interpretation of Tables 20 to 37 will be illustrated with the values given for stature in the first row of Table 20.

Table 20

Stature: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	9.98	18.0		72.0
	4	15	to		7	15	5.17	7.9		31.6
	7	15	to		10	15	4.25	6.0		24.1†
	10	15	to	1	1	15	3.36	4.5		18.0
1	1	15	to	1	4	15	2.96	3.8		15.1
1	4	15	to	1	7	15	3.28	4.0		16.1
1	7	15	to	1	10	15	2.79	3.3		13.2
1	10	15	to	2	1	15	2.63	3.0		12.1
2	1	15	to	2	4	15	1.26	1.4		5.6
2	4	15	to	2	7	15	2.46	2.7		10.8
2	7	15	to	2	10	15	2.23	2.4		9.5
2	10	15	to	3	3	0	2.04		2.1*	5.7
3	3	0	to	3	9	0	3.82		3.9	7.8
3	9	0	to	4	3	0	3.33		3.3	6.6
4	3	0	to	4	9	0	3.49		3.3	6.6
4	9	0	to	5	3	0	2.92		2.7	5.4
5	3	0	to	5	9	0	3.09		2.8	5.6
5	9	0	to	6	3	0	2.92		2.6	5.1
6	3	0	to	7	0	0	4.50		3.8**	5.1
7	0	0	to	8	0	0	6.22			5.1
8	0	0	to	9	0	0	5.58			4.4
9	0	0	to	10	0	0	5.23			3.9
10	0	0	to	11	0	0	4.26			3.1
11	0	0	to	12	0	0	4.61			3.2
12	0	0	to	13	0	0	5.51			3.7
13	0	0	to	14	0	0	6.08			4.0
14	0	0	to	15	0	0	5.76			3.6
15	0	0	to	16	0	0	4.58			2.8
16	0	0	to	17	0	0	3.78			2.2
17	0	0	to	18	0	0	.63			.4

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 6.0 multiplied by 4 equals 24.0, not 24.1. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 21

Sitting Height: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	4.96	13.0		51.8†
	4	15	to		7	15	2.76	6.4		25.5
	7	15	to		10	15	1.94	4.2		16.9
	10	15	to	1	1	15	1.48	3.1		12.4
1	1	15	to	1	4	15	1.08	2.2		8.8
1	4	15	to	1	7	15	1.72	3.4		13.7
1	7	15	to	1	10	15	.92	1.8		7.0
1	10	15	to	2	1	15	1.11	2.1		8.4
2	1	15	to	2	4	15	.44	.8		3.3
2	4	15	to	2	7	15	.98	1.8		7.2
2	7	15	to	2	10	15	.92	1.6		6.6
2	10	15	to	3	3	0	.73		1.3*	3.5
3	3	0	to	3	9	0	1.63		2.8	5.7
3	9	0	to	4	3	0	1.15		1.9	3.9
4	3	0	to	4	9	0	1.33		2.2	4.4
4	9	0	to	5	3	0	1.22		2.0	4.0
5	3	0	to	5	9	0	1.47		2.3	4.7
5	9	0	to	6	3	0	.99		1.6	3.1
6	3	0	to	7	0	0	1.68		2.6**	3.4
7	0	0	to	8	0	0	2.51			3.8
8	0	0	to	9	0	0	2.06			3.0
9	0	0	to	10	0	0	2.19			3.1
10	0	0	to	11	0	0	1.53			2.1
11	0	0	to	12	0	0	1.79			2.4
12	0	0	to	13	0	0	2.46			3.2
13	0	0	to	14	0	0	2.99			3.8
14	0	0	to	15	0	0	3.03			3.7
15	0	0	to	16	0	0	2.93			3.4
16	0	0	to	17	0	0	2.17			2.5
17	0	0	to	18	0	0	1.11			1.2

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 13.0 multiplied by 4 equals 52.0, not 51.8. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 22

Bi-Deltoid Diameter: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centi-meters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	1.98	12.5		49.9†
	4	15	to		7	15	1.60	9.0		35.8
	7	15	to		10	15	.89	4.6		18.2
	10	15	to	1	1	15	.72	3.5		14.1
1	1	15	to	1	4	15	.39	1.9		7.5
1	4	15	to	1	7	15	.31	1.5		5.9
1	7	15	to	1	10	15	.32	1.5		5.8
1	10	15	to	2	1	15	.52	2.4		9.5
2	1	15	to	2	4	15	.19	.8		3.3
2	4	15	to	2	7	15	.29	1.3		5.0
2	7	15	to	2	10	15	.18	.8		3.1
2	10	15	to	3	3	0	.56		2.4*	6.5
3	3	0	to	3	9	0	.44		1.9	3.7
3	9	0	to	4	3	0	.52		2.1	4.3
4	3	0	to	4	9	0	.57		2.3	4.6
4	9	0	to	5	3	0	.53		2.1	4.2
5	3	0	to	5	9	0	.52		2.0	4.0
5	9	0	to	6	3	0	.32		1.2	2.4
6	3	0	to	7	0	0	.97		3.6**	4.9
7	0	0	to	8	0	0	1.34			4.8
8	0	0	to	9	0	0	1.01			3.5
9	0	0	to	10	0	0	1.10			3.7
10	0	0	to	11	0	0	.90			2.9
11	0	0	to	12	0	0	1.09			3.4
12	0	0	to	13	0	0	1.12			3.4
13	0	0	to	14	0	0	1.60			4.7
14	0	0	to	15	0	0	1.48			4.1
15	0	0	to	16	0	0	1.37			3.7
16	0	0	to	17	0	0	1.23			3.2
17	0	0	to	18	0	0	.73			1.8

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 12.5 multiplied by 4 equals 50.0, not 49.9. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 23

Bi-Trochanteric Diameter: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	2.14	18.0		71.9†
	4	15	to		7	15	1.12	8.0		31.8
	7	15	to		10	15	.49	3.2		12.9
	10	15	to	1	1	15	.13	.8		3.3
1	1	15	to	1	4	15	.09	.6		2.4
1	4	15	to	1	7	15	.49	3.1		12.4
1	7	15	to	1	10	15	.33	2.0		8.0
1	10	15	to	2	1	15	.20	1.2		4.8
2	1	15	to	2	4	15	.19	1.1		4.5
2	4	15	to	2	7	15	.40	2.3		9.4
2	7	15	to	2	10	15	.31	1.8		7.2
2	10	15	to	3	3	0	.34		1.9*	5.1
3	3	0	to	3	9	0	.52		2.9	5.7
3	9	0	to	4	3	0	.36		1.9	3.8
4	3	0	to	4	9	0	.40		2.1	4.2
4	9	0	to	5	3	0	.37		1.9	3.8
5	3	0	to	5	9	0	.42		2.1	4.2
5	9	0	to	6	3	0	.37		1.8	3.6
6	3	0	to	7	0	0	.71		3.4**	4.6
7	0	0	to	8	0	0	.95			4.5
8	0	0	to	9	0	0	.95			4.3
9	0	0	to	10	0	0	1.12			4.9
10	0	0	to	11	0	0	.75			3.1
11	0	0	to	12	0	0	1.07			4.3
12	0	0	to	13	0	0	1.28			4.9
13	0	0	to	14	0	0	2.10			7.7
14	0	0	to	15	0	0	.65			2.2
15	0	0	to	16	0	0	1.09			3.6
16	0	0	to	17	0	0	.88			2.8
17	0	0	to	18	0	0	.19			.6

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 18 multiplied by 4 equals 72.0, not 71.9. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 24

Transverse Diameter of Thorax: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	1.77	14.6		58.5†
	4	15	to		7	15	.83	6.0		23.9
	7	15	to		10	15	.68	4.7		18.6
	10	15	to	1	1	15	.34	2.2		9.0
1	1	15	to	1	4	15	.36	2.3		9.1
1	4	15	to	1	7	15	.19	1.2		4.9
1	7	15	to	1	10	15	.30	1.9		7.5
1	10	15	to	2	1	15	.12	.7		2.9
2	1	15	to	2	4	15	.05	.3		1.2
2	4	15	to	2	7	15	.12	.7		2.8
2	7	15	to	2	10	15	.04	.2		.9
2	10	15	to	3	3	0	.19		1.1*	3.0
3	3	0	to	3	9	0	.30		1.8	3.6
3	9	0	to	4	3	0	.26		1.5	3.0
4	3	0	to	4	9	0	.23		1.3	2.6
4	9	0	to	5	3	0	.31		1.8	3.5
5	3	0	to	5	9	0	.32		1.7	3.5
5	9	0	to	6	3	0	.20		1.1	2.1
6	3	0	to	7	0	0	.59		3.1**	4.2
7	0	0	to	8	0	0	.76			4.0
8	0	0	to	9	0	0	.75			3.7
9	0	0	to	10	0	0	.83			4.0
10	0	0	to	11	0	0	.55			2.6
11	0	0	to	12	0	0	.74			3.3
12	0	0	to	13	0	0	1.10			4.8
13	0	0	to	14	0	0	1.08			4.5
14	0	0	to	15	0	0	.94			3.8
15	0	0	to	16	0	0	.96			3.7
16	0	0	to	17	0	0	.72			2.7
17	0	0	to	18	0	0	.65			2.3

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 14.6 multiplied by 4 equals 58.4, not 58.5. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 25

Antero-Posterior Diameter of Thorax: Absolute Gain or Loss and Percentage Rate Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain or Loss in Centimeters	Percentage Rate		
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	Annual
	1	15	to		4	15	.96	9.4		37.7†
	4	15	to		7	15	.42	3.7		14.9
	7	15	to		10	15	.40	3.4		13.8
	10	15	to	1	1	15	.16	1.3		5.2
1	1	15	to	1	4	15	.37	3.1		12.2
1	4	15	to	1	7	15	.10	.8		3.1
1	7	15	to	1	10	15	.06	.5		1.9
1	10	15	to	2	1	15	.01	.0		.2
2	1	15	to	2	4	15	–.14	–1.1		–4.3
2	4	15	to	2	7	15	–.04	– .4		–1.4
2	7	15	to	2	10	15	.04	.3		1.4
2	10	15	to	3	3	0	.11		.9*	2.4
3	3	0	to	3	9	0	.19		1.5	3.1
3	9	0	to	4	3	0	.32		2.5	5.0
4	3	0	to	4	9	0	.12		.9	1.8
4	9	0	to	5	3	0	.27		2.0	4.1
5	3	0	to	5	9	0	.22		1.6	3.2
5	9	0	to	6	3	0	.28		2.0	4.0
6	3	0	to	7	0	0	.43		3.1**	4.1
7	0	0	to	8	0	0	.49			3.4
8	0	0	to	9	0	0	.42			2.8
9	0	0	to	10	0	0	.51			3.3
10	0	0	to	11	0	0	.32			2.0
11	0	0	to	12	0	0	.73			4.5
12	0	0	to	13	0	0	.79			4.7
13	0	0	to	14	0	0	.84			4.7
14	0	0	to	15	0	0	.69			3.7
15	0	0	to	16	0	0	.68			3.5
16	0	0	to	17	0	0	.70			3.5
17	0	0	to	18	0	0	.84			4.0

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 9.4 multiplied by 4 equals 37.6, not 37.7. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 26

Thoracic Circumference: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval						Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days	Years	Months	Days		Quarterly	Semi-annual	
	1	15 to		4	15	4.18	10.9		43.8†
	4	15 to		7	15	2.31	5.5		21.8
	7	15 to		10	15	2.00	4.5		17.9
	10	15 to	1	1	15	1.08	2.3		9.3
1	1	15 to	1	4	15	.90	1.9		7.5
1	4	15 to	1	7	15	.69	1.4		5.7
1	7	15 to	1	10	15	.76	1.5		6.2
1	10	15 to	2	1	15	.07	.1		.5
2	1	15 to	2	4	15	.27	.5		2.2
2	4	15 to	2	7	15	.36	.7		2.8
2	7	15 to	2	10	15	–.05	– .1		– .4
2	10	15 to	3	3	0	.56		1.1*	3.0
3	3	0 to	3	9	0	.93		1.8	3.6
3	9	0 to	4	3	0	.78		1.5	3.0
4	3	0 to	4	9	0	.66		1.2	2.5
4	9	0 to	5	3	0	1.20		2.2	4.5
5	3	0 to	5	9	0	1.02		1.9	3.7
5	9	0 to	6	3	0	.94		1.7	3.4
6	3	0 to	7	0	0	1.79		3.2**	4.2
7	0	0 to	8	0	0	2.31			3.9
8	0	0 to	9	0	0	2.09			3.4
9	0	0 to	10	0	0	2.60			4.1
10	0	0 to	11	0	0	1.93			2.9
11	0	0 to	12	0	0	2.37			3.5
12	0	0 to	13	0	0	3.33			4.8
13	0	0 to	14	0	0	3.48			4.7
14	0	0 to	15	0	0	3.20			4.2
15	0	0 to	16	0	0	3.23			4.0
16	0	0 to	17	0	0	2.24			2.7
17	0	0 to	18	0	0	1.45			1.7

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 10.9 multiplied by 4 equals 43.6, not 43.8. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 27

Body Weight: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Kilo-grams	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	3.30	77.9		311.6
	4	15	to		7	15	1.44	19.2		76.6†
	7	15	to		10	15	1.16	13.0		51.9
	10	15	to	1	1	15	.71	7.0		28.0
1	1	15	to	1	4	15	.56	5.1		20.5
1	4	15	to	1	7	15	.91	8.0		31.9
1	7	15	to	1	10	15	.57	4.6		18.5
1	10	15	to	2	1	15	.71	5.5		21.9
2	1	15	to	2	4	15	.28	2.1		8.3
2	4	15	to	2	7	15	.80	5.8		23.1
2	7	15	to	2	10	15	.38	2.6		10.3
2	10	15	to	3	3	0	.59		3.9*	10.5
3	3	0	to	3	9	0	1.08		6.9	13.8
3	9	0	to	4	3	0	.76		4.6	9.1
4	3	0	to	4	9	0	.97		5.6	11.1
4	9	0	to	5	3	0	1.04		5.6	11.2
5	3	0	to	5	9	0	.98		5.0	10.0
5	9	0	to	6	3	0	1.05		5.1	10.2
6	3	0	to	7	0	0	2.02		9.4**	12.5
7	0	0	to	8	0	0	2.82			12.0
8	0	0	to	9	0	0	2.64			10.0
9	0	0	to	10	0	0	3.56			12.3
10	0	0	to	11	0	0	2.76			8.5
11	0	0	to	12	0	0	3.37			9.5
12	0	0	to	13	0	0	4.99			12.9
13	0	0	to	14	0	0	4.98			11.4
14	0	0	to	15	0	0	6.32			13.0
15	0	0	to	16	0	0	3.42			6.2
16	0	0	to	17	0	0	4.07			7.0
17	0	0	to	18	0	0	2.24			3.6

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 19.2 multiplied by 4 equals 76.8, not 76.6. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 28

Maximum Head Length: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval						Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days	Years	Months	Days		Quarterly	Semi-annual	
	1	15 to		4	15	.95	7.1		28.3†
	4	15 to		7	15	.71	5.0		19.8
	7	15 to		10	15	.65	4.3		17.3
	10	15 to	1	1	15	.25	1.6		6.4
1	1	15 to	1	4	15	.39	2.5		9.9
1	4	15 to	1	7	15	.26	1.6		6.4
1	7	15 to	1	10	15	.17	1.0		4.1
1	10	15 to	2	1	15	.26	1.6		6.3
2	1	15 to	2	4	15	.07	.4		1.6
2	4	15 to	2	7	15	.00	.0		.0
2	7	15 to	2	10	15	.09	.5		2.1
2	10	15 to	3	3	0	–.04		–.2*	–.6
3	3	0 to	3	9	0	.06		.3	.7
3	9	0 to	4	3	0	.12		.7	1.4
4	3	0 to	4	9	0	.18		1.1	2.1
4	9	0 to	5	3	0	.13		.7	1.5
5	3	0 to	5	9	0	.10		.6	1.1
5	9	0 to	6	3	0	.03		.2	.3
6	3	0 to	7	0	0	.10		.5**	.7
7	0	0 to	8	0	0	.11			.6
8	0	0 to	9	0	0	.18			1.0
9	0	0 to	10	0	0	.21			1.2
10	0	0 to	11	0	0	.04			.2
11	0	0 to	12	0	0	.13			.7
12	0	0 to	13	0	0	.13			.7
13	0	0 to	14	0	0	.09			.5
14	0	0 to	15	0	0	.15			.8
15	0	0 to	16	0	0	.23			1.2
16	0	0 to	17	0	0	.19			1.0
17	0	0 to	18	0	0	.00			.0

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 7.1 multiplied by 4 equals 28.4, not 28.3. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 29

Maximum Head Breadth: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	.95	8.7		34.8
	4	15	to		7	15	.77	6.5		26.0
	7	15	to		10	15	.33	2.6		10.4
	10	15	to	1	1	15	.22	1.7		6.8
1	1	15	to	1	4	15	.25	1.9		7.6
1	4	15	to	1	7	15	.12	.9		3.6
1	7	15	to	1	10	15	.08	.6		2.4
1	10	15	to	2	1	15	.12	.9		3.5†
2	1	15	to	2	4	15	.04	.3		1.3
2	4	15	to	2	7	15	.10	.7		2.9
2	7	15	to	2	10	15	.02	.2		.6
2	10	15	to	3	3	0	.06		.4*	1.1
3	3	0	to	3	9	0	.19		1.3	2.7
3	9	0	to	4	3	0	.07		.5	1.0
4	3	0	to	4	9	0	.08		.6	1.2
4	9	0	to	5	3	0	.07		.5	1.0
5	3	0	to	5	9	0	.03		.2	.4
5	9	0	to	6	3	0	–.02		–.1	–.3
6	3	0	to	7	0	0	.09		.6**	.8
7	0	0	to	8	0	0	.14			.9
8	0	0	to	9	0	0	.08			.5
9	0	0	to	10	0	0	.07			.5
10	0	0	to	11	0	0	.02			.1
11	0	0	to	12	0	0	.06			.4
12	0	0	to	13	0	0	.10			.7
13	0	0	to	14	0	0	.04			.3
14	0	0	to	15	0	0	.10			.7
15	0	0	to	16	0	0	.03			.2
16	0	0	to	17	0	0	.13			.8
17	0	0	to	18	0	0	.04			.2

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that .9 multiplied by 4 equals 3.6, not 3.5. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 30

Bi-Condylar Diameter of Left Femur: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	.62	14.5		58.1†
	4	15	to		7	15	.35	7.3		29.1
	7	15	to		10	15	.19	3.6		14.6
	10	15	to	1	1	15	.21	3.9		15.6
1	1	15	to	1	4	15	.18	3.2		13.0
1	4	15	to	1	7	15	.14	2.5		9.8
1	7	15	to	1	10	15	.08	1.3		5.4
1	10	15	to	2	1	15	.20	3.4		13.5
2	1	15	to	2	4	15	.09	1.5		6.1
2	4	15	to	2	7	15	.19	3.0		12.1
2	7	15	to	2	10	15	.14	2.2		8.7
2	10	15	to	3	3	0	.16		2.3*	6.3
3	3	0	to	3	9	0	.16		2.3	4.6
3	9	0	to	4	3	0	.13		1.8	3.7
4	3	0	to	4	9	0	.09		1.3	2.7
4	9	0	to	5	3	0	.14		2.0	4.0
5	3	0	to	5	9	0	.06		.9	1.8
5	9	0	to	6	3	0	.12		1.6	3.1
6	3	0	to	7	0	0	.22		3.0**	4.0
7	0	0	to	8	0	0	.33			4.3
8	0	0	to	9	0	0	.20			2.4
9	0	0	to	10	0	0	.21			2.5
10	0	0	to	11	0	0	.08			1.0
11	0	0	to	12	0	0	.29			3.3
12	0	0	to	13	0	0	.38			4.3
13	0	0	to	14	0	0	.29			3.1
14	0	0	to	15	0	0	.05			.6
15	0	0	to	16	0	0	.06			.6
16	0	0	to	17	0	0	.05			.5
17	0	0	to	18	0	0	.00			.0

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

† It will be noticed that 14.5 multiplied by 4 equals 58.0, not 58.1. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 31

Bi-Condylar Diameter of Left Humerus: Absolute Gain and Percentage Increment Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Centimeters	Percentage Increment		Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	
	1	15	to		4	15	.37	11.7		46.9†
	4	15	to		7	15	.22	6.2		24.7
	7	15	to		10	15	.18	5.0		19.8
	10	15	to	1	1	15	.09	2.3		9.1
1	1	15	to	1	4	15	.09	2.4		9.5
1	4	15	to	1	7	15	.05	1.2		4.7
1	7	15	to	1	10	15	.00	.0		.1
1	10	15	to	2	1	15	.06	1.4		5.6
2	1	15	to	2	4	15	.11	2.7		10.9
2	4	15	to	2	7	15	.06	1.4		5.8
2	7	15	to	2	10	15	.26	5.9		23.6
2	10	15	to	3	3	0	.09		1.9*	5.2
3	3	0	to	3	9	0	.00		–.1	–.1
3	9	0	to	4	3	0	.00		.0	.0
4	3	0	to	4	9	0	.10		2.1	4.2
4	9	0	to	5	3	0	.00		–.1	–.2
5	3	0	to	5	9	0	.05		1.1	2.2
5	9	0	to	6	3	0	.08		1.7	3.4
6	3	0	to	7	0	0	.16		3.2**	4.3
7	0	0	to	8	0	0	.21			4.1
8	0	0	to	9	0	0	.18			3.3
9	0	0	to	10	0	0	.09			1.6
10	0	0	to	11	0	0	.04			.8
11	0	0	to	12	0	0	.19			3.4
12	0	0	to	13	0	0	.25			4.3
13	0	0	to	14	0	0	.33			5.5
14	0	0	to	15	0	0	.15			2.4
15	0	0	to	16	0	0	.17			2.6
16	0	0	to	17	0	0	.13			1.9
17	0	0	to	18	0	0	.14			2.0

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 11.7 multiplied by 4 equals 46.8, not 46.9. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 32

Strength of Grip: Absolute Gain and Percentage Increment Values for Eighteen Age Intervals, Covering the Period from Three Years, Three Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Kilo-grams	Semi-annual Percentage Increment	Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days			
3	3	0	to	3	9	0	1.88	37.2	74.4
3	9	0	to	4	3	0	1.20	17.3	34.5†
4	3	0	to	4	9	0	1.57	19.3	38.7
4	9	0	to	5	3	0	.92	9.5	18.9
5	3	0	to	5	9	0	.45	4.2	8.5
5	9	0	to	6	3	0	.67	10.5*	12.0
6	3	0	to	7	0	0	1.23		14.0
7	0	0	to	8	0	0	2.83		21.9
8	0	0	to	9	0	0	2.09		13.2
9	0	0	to	10	0	0	2.43		13.6
10	0	0	to	11	0	0	2.17		10.7
11	0	0	to	12	0	0	2.50		11.1
12	0	0	to	13	0	0	4.18		16.7
13	0	0	to	14	0	0	4.75		16.3
14	0	0	to	15	0	0	4.95		14.6
15	0	0	to	16	0	0	5.89		15.2
16	0	0	to	17	0	0	3.54		7.9
17	0	0	to	18	0	0	4.13		8.6

*The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 17.3 multiplied by 4 equals 34.6, not 34.5. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

During the quarter year interval between one and one-half months and four and one-half months of age the mean gain of Iowa City white males in crown-heel length is approximately 10 cm. Over the same quaterly interval the mean percentage increment in crown-heel length is 18 per cent. Stating this latter in annual terms, between one and one-half and four and one-half months of age Iowa City white males as a group are growing in crown-heel length at the rate of 72 per cent increase per year.

In the matter of graphic representation of percentage rate trends, a single graph for each measurement based on the annual percent-

Table 33

Breathing Capacity: Absolute Gain and Percentage Increment Values for Fourteen Age Intervals, Covering the Period from Five Years, Three Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain in Cubic Inches	Semi-annual Percentage Increment	Annual Rate of Percentage Increment
Years	Months	Days		Years	Months	Days			
5	3	0	to	5	9	0	10.72	19.1	38.3[†]
5	9	0	to	6	3	0	4.90	7.3	14.7
6	3	0	to	7	0	0	6.92	9.7[*]	12.9
7	0	0	to	8	0	0	13.91		17.7
8	0	0	to	9	0	0	11.02		11.9
9	0	0	to	10	0	0	12.03		11.6
10	0	0	to	11	0	0	12.04		10.4
11	0	0	to	12	0	0	14.38		11.3
12	0	0	to	13	0	0	15.53		10.9
13	0	0	to	14	0	0	22.46		14.3
14	0	0	to	15	0	0	23.92		13.3
15	0	0	to	16	0	0	23.64		11.6
16	0	0	to	17	0	0	20.02		8.8
17	0	0	to	18	0	0	9.76		3.9

[*] The percentage gain over a nine month interval is given by this figure.

[†] It will be noticed that 19.1 multiplied by 4 equals 38.2, not 38.3. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

age rate values might have been employed. Or three graphs for each measurement might have been afforded—one covering the age period over which there are quarterly rates, another covering the semiannual rate age span, and the third over the span of years for which annual rates are the directly obtained values. Preliminary experimentation showed neither of these procedures to be as desirable as a compromise.

Three graphs for each measurement were found to be unwarranted since the semiannual and annual curves when drawn separately showed nothing that was not portrayed with equal clearness (after converting the former to annual terms) when the two were combined. On the other hand, single graphs in annual terms gave unnecessarily crude percentage rate plots owing to the rapid and marked decrease in percentage growth common to most bodily

Table 34

Skin and Subcutaneous Tissue at Thorax Front: Absolute Gain or Loss and Percentage Rate Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval						Gain or Loss in Millimeters	Percentage Rate		
Years	Months	Days	Years	Months	Days		Quarterly	Semi-annual	Annual
	1	15 to		4	15	.62	16.1		64.5†
	4	15 to		7	15	–.46	–10.3		–41.0
	7	15 to		10	15	–.36	– 9.1		–36.3
	10	15 to	1	1	15	–.08	– 2.2		– 8.9
1	1	15 to	1	4	15	.17	4.9		19.7
1	4	15 to	1	7	15	–.23	– 6.3		–25.2
1	7	15 to	1	10	15	–.06	– 1.8		– 7.0
1	10	15 to	2	1	15	–.08	– 2.3		– 9.3
2	1	15 to	2	4	15	–.07	– 2.0		– 7.9
2	4	15 to	2	7	15	–.02	– .5		– 2.0
2	7	15 to	2	10	15	.23	7.1		28.3
2	10	15 to	3	3	0	.01		.4*	1.1
3	3	0 to	3	9	0	–.07		–2.1	– 4.1
3	9	0 to	4	3	0	–.27		–7.9	–15.9
4	3	0 to	4	9	0	–.05		–1.5	– 3.1
4	9	0 to	5	3	0	–.07		–2.2	– 4.4
5	3	0 to	5	9	0	.06		2.1	4.3
5	9	0 to	6	3	0	–.25		–8.2	–16.3
6	3	0 to	7	0	0	.21		7.5**	10.0
7	0	0 to	8	0	0	.19			6.2
8	0	0 to	9	0	0	.37			11.4
9	0	0 to	10	0	0	–.11			– 3.0
10	0	0 to	11	0	0	.47			13.4
11	0	0 to	12	0	0	.20			5.0
12	0	0 to	13	0	0	.37			8.9
13	0	0 to	14	0	0	.19			4.2
14	0	0 to	15	0	0	.10			2.1
15	0	0 to	16	0	0	–.18			– 3.7
16	0	0 to	17	0	0	.05			1.1
17	0	0 to	18	0	0	.11			2.3

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 16.1 multiplied by 4 equals 64.4, not 64.5. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 35

Skin and Subcutaneous Tissue at Thorax Back: Absolute Gain or Loss and Percentage Rate Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain or Loss in Millimeters	Percentage Rate		
Years	Months	Days		Years	Months	Days		Quarterly	Semiannual	Annual
	1	15	to		4	15	.61	14.3		57.0†
	4	15	to		7	15	–.48	– 9.7		–39.0
	7	15	to		10	15	–.18	– 4.0		–16.1
	10	15	to	1	1	15	.01	.2		.7
1	1	15	to	1	4	15	.03	.8		3.2
1	4	15	to	1	7	15	–.02	– .6		– 2.3
1	7	15	to	1	10	15	–.13	– 3.1		–12.6
1	10	15	to	2	1	15	–.15	– 3.8		–15.0
2	1	15	to	2	4	15	–.09	– 2.2		– 8.6
2	4	15	to	2	7	15	.22	5.8		23.2
2	7	15	to	2	10	15	.20	5.0		20.0
2	10	15	to	3	3	0	.06		1.3*	3.5
3	3	0	to	3	9	0	–.29		–6.7	–13.4
3	9	0	to	4	3	0	–.27		–6.6	–13.2
4	3	0	to	4	9	0	–.17		–4.4	– 8.9
4	9	0	to	5	3	0	.14		4.0	7.9
5	3	0	to	5	9	0	.01		.2	.4
5	9	0	to	6	3	0	–.19		–5.1	–10.2
6	3	0	to	7	0	0	.31		8.7**	11.5
7	0	0	to	8	0	0	.12			3.1
8	0	0	to	9	0	0	.05			1.2
9	0	0	to	10	0	0	–.04			– 1.0
10	0	0	to	11	0	0	.25			6.2
11	0	0	to	12	0	0	.15			3.5
12	0	0	to	13	0	0	.23			5.2
13	0	0	to	14	0	0	.11			2.4
14	0	0	to	15	0	0	.11			2.3
15	0	0	to	16	0	0	.12			2.5
16	0	0	to	17	0	0	.19			3.8
17	0	0	to	18	0	0	.24			4.6

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 14.3 multiplied by 4 equals 57.2, not 57.0. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 36

Skin and Subcutaneous Tissue at Upperarm Front: Absolute Gain or Loss and Percentage Rate Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain or Loss in Millimeters	Percentage Rate		
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	Annual
	1	15	to		4	15	.72	19.8		79.1†
	4	15	to		7	15	.30	6.9		27.6
	7	15	to		10	15	–.48	–10.3		–41.1
	10	15	to	1	1	15	.08	1.8		7.4
1	1	15	to	1	4	15	.00	– .1		– .4
1	4	15	to	1	7	15	–.08	– 2.0		– 7.8
1	7	15	to	1	10	15	–.31	– 7.3		–29.3
1	10	15	to	2	1	15	.05	1.3		5.4
2	1	15	to	2	4	15	–.26	– 6.7		–26.6
2	4	15	to	2	7	15	.42	11.5		46.2
2	7	15	to	2	10	15	–.05	– 1.1		– 4.5
2	10	15	to	3	3	0	.35		8.6*	22.9
3	3	0	to	3	9	0	–.20		–4.6	– 9.2
3	9	0	to	4	3	0	.20		4.9	9.8
4	3	0	to	4	9	0	–.32		–7.3	–14.7
4	9	0	to	5	3	0	.00		.1	.2
5	3	0	to	5	9	0	–.08		–1.9	– 3.9
5	9	0	to	6	3	0	–.48		–11.9	–23.9
6	3	0	to	7	0	0	.18		5.1**	6.9
7	0	0	to	8	0	0	–.03			– .8
8	0	0	to	9	0	0	.11			3.0
9	0	0	to	10	0	0	–.04			– 1.1
10	0	0	to	11	0	0	.34			9.1
11	0	0	to	12	0	0	–.09			– 2.2
12	0	0	to	13	0	0	.02			.5
13	0	0	to	14	0	0	–.12			– 3.0
14	0	0	to	15	0	0	–.27			– 7.0
15	0	0	to	16	0	0	–.27			– 7.5
16	0	0	to	17	0	0	–.09			– 2.7
17	0	0	to	18	0	0	–.03			– .9

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 19.8 multiplied by 4 equals 79.2, not 79.1. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

Table 37

Skin and Subcutaneous Tissue at Upperarm Back: Absolute Gain or Loss and Percentage Rate Values for Thirty Age Intervals, Covering the Period from One and One-Half Months to Eighteen Years, on Iowa City White Males

Age Interval							Gain or Loss in Milli-meters	Percentage Rate		
Years	Months	Days		Years	Months	Days		Quarterly	Semi-annual	Annual
	1	15	to		4	15	.62	12.6		50.3†
	4	15	to		7	15	.28	5.0		20.0
	7	15	to		10	15	–.10	– 1.7		– 6.8
	10	15	to	1	1	15	.06	1.1		4.3
1	1	15	to	1	4	15	.06	1.1		4.4
1	4	15	to	1	7	15	–.23	– 3.9		–15.6
1	7	15	to	1	10	15	–.11	– 2.0		– 8.1
1	10	15	to	2	1	15	.16	2.8		11.3
2	1	15	to	2	4	15	.11	1.9		7.7
2	4	15	to	2	7	15	–.10	– 1.8		– 7.0
2	7	15	to	2	10	15	.27	4.7		18.8
2	10	15	to	3	3	0	.34		5.7*	15.1
3	3	0	to	3	9	0	–.19		–3.1	– 6.2
3	9	0	to	4	3	0	–.07		–1.2	– 2.4
4	3	0	to	4	9	0	.00		.0	.0
4	9	0	to	5	3	0	–.22		–3.7	– 7.3
5	3	0	to	5	9	0	.05		.8	1.7
5	9	0	to	6	3	0	–.05		– .8	– 1.6
6	3	0	to	7	0	0	.30		5.2**	6.9
7	0	0	to	8	0	0	.17			2.8
8	0	0	to	9	0	0	.16			2.7
9	0	0	to	10	0	0	–.02			– .3
10	0	0	to	11	0	0	.53			8.3
11	0	0	to	12	0	0	–.02			– .3
12	0	0	to	13	0	0	–.24			– 3.5
13	0	0	to	14	0	0	–.28			– 4.2
14	0	0	to	15	0	0	–.55			– 8.6
15	0	0	to	16	0	0	–.42			– 7.2
16	0	0	to	17	0	0	.05			.9
17	0	0	to	18	0	0	–.06			– 1.1

*This value represents the percentage increase for four and one-half rather than six months.

**The percentage gain over a nine month interval is given by this figure.

†It will be noticed that 12.6 multiplied by 4 equals 50.4, not 50.3. Seeming inaccuracies of this type are due to the fact that all computations were carried to four decimal places.

dimensions during the first year or two of life. This is in contrast to the relatively small increments and decrements in rate during the succeeding years.

A few figures will readily indicate the crudeness that would characterize single graph analysis. Iowa City white males increase in body weight at the rate of 312 per cent per year over the interval from one and one-half months to four and one-half months, at the rate of 22 per cent per year for the twenty-two and one-half to twenty-five and one-half months interval, and at the rate of 7 per cent per year between the sixteenth and seventeenth years. Obviously a percentage rate trend for this measurement would show a long, almost perpendicular decline over the first year or so and would unduly minimize the changes in rate of growth which occur between this age and the seventeenth year. Similar figures might be cited for other measurements. For instance, over the same age intervals as used for weight, stature shows gains of 72, 12.1, and 2.2 per cent, respectively.

In view of the above findings, percentage rates of growth are graphed on the quarterly basis between one and one-half and thirty-four and one-half months of age and in annual terms between thirty-four and one-half months and eighteen years. This procedure reduces the number of graphs on each measurement to a limit consistent with the counter objective of clearly exhibiting changes in phase (changes from acceleration to retardation in rate and vice versa) over the entire age period under analysis.

QUARTERLY PERCENTAGE RATE CURVES

Percentage rate trend lines for each of sixteen bodily dimensions of Iowa City white males are given in Figures 9 to 12. These curves extend over the age period from 1½-4½ months to 31½-34½ months and are drawn to the quarterly percentage rate values presented in Tables 20 to 31 and 34 to 37. The values for each measurement are plotted on a separate graph.

Since the sixteen graphs have a common abscissa scale, they are interpreted in like manner. The point plotted directly above the abscissa scale marking of "1½-4½" gives, by its corresponding ordinate scale value, the mean rate of growth in the measurement during the quarterly interval included between the limits of one and one-half months and four and one-half months. The next plotted point represents the mean percentage rate for the quarter year from four and one-half months to seven and one-half months of age. Succeeding points have similar meanings.

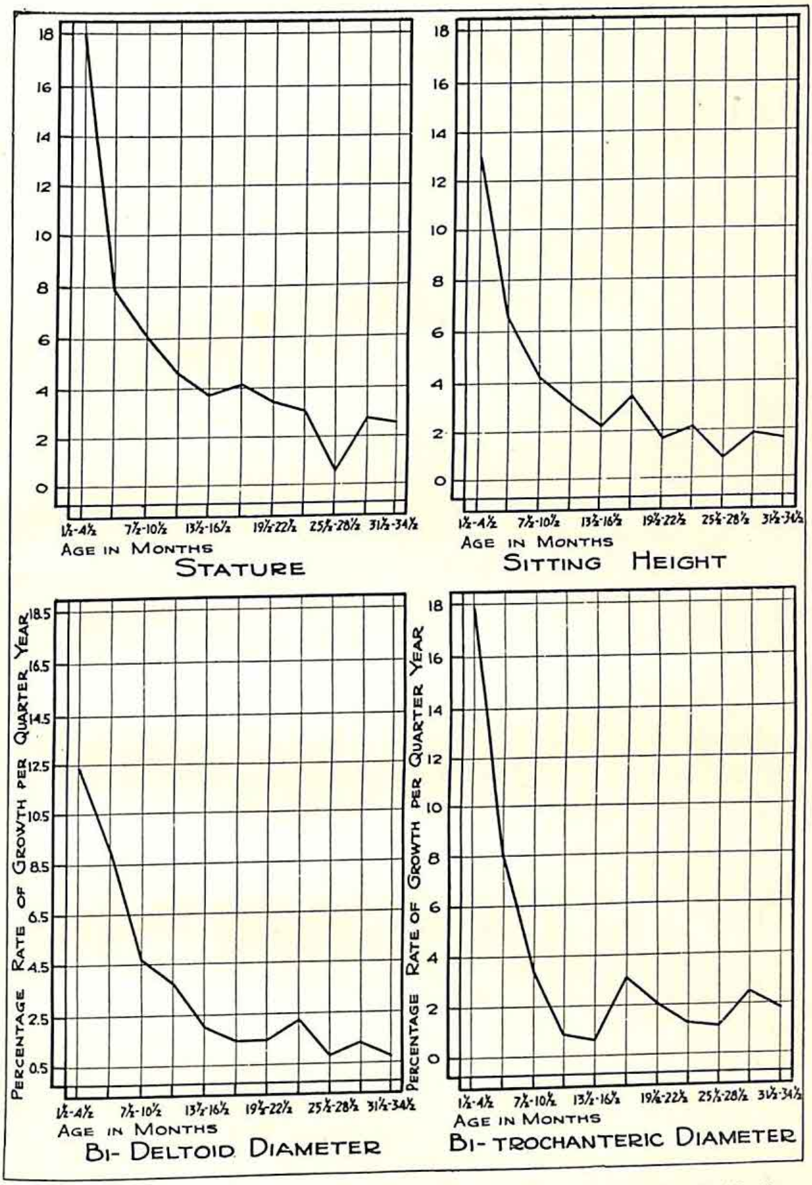


Figure 9. Relative velocity trends for stature, sitting height, bi-deltoid diameter, and bi-trochanteric diameter on Iowa City white males are shown. The trends cover approximately the first three years of postnatal life and are plotted to the four series of quarterly percentage increment values given in Tables 20 to 23 inclusive.

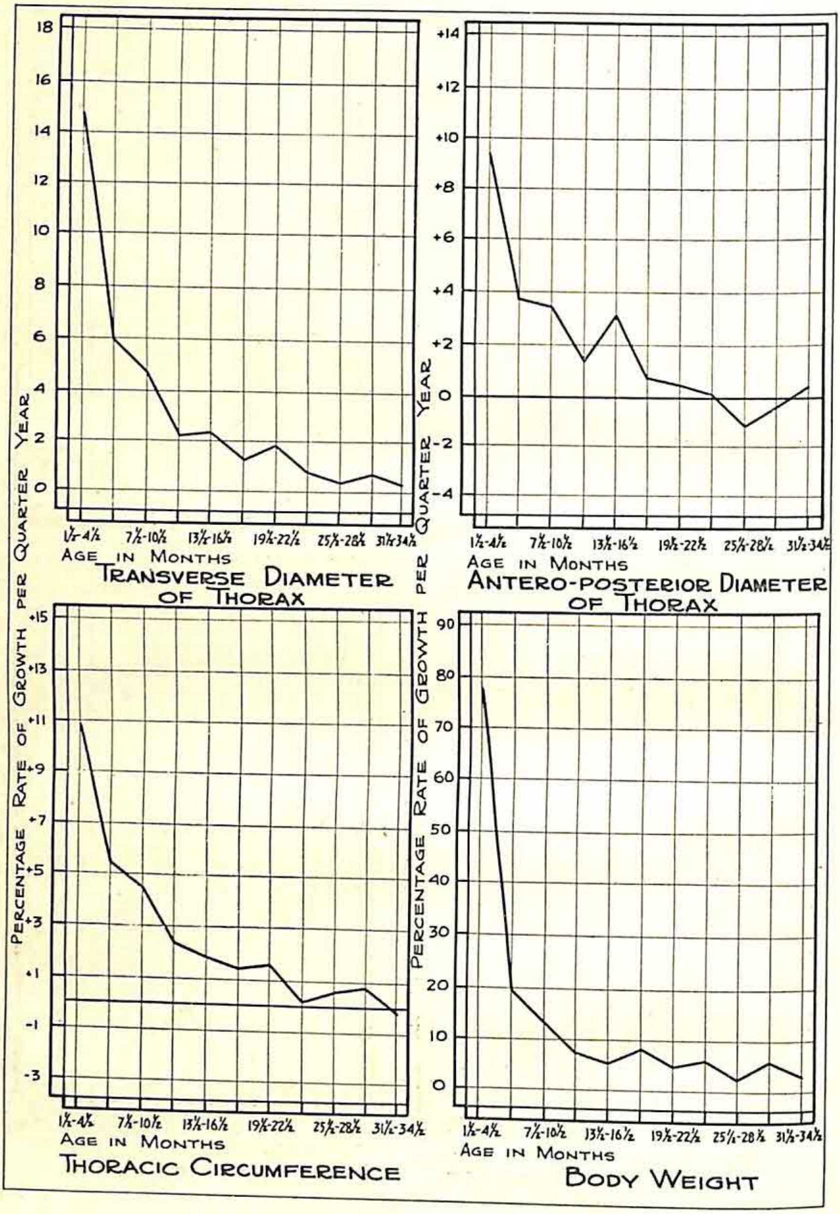


Figure 10. Quarterly "percentage rate" curves are given for transverse diameter of thorax, antero-posterior diameter of thorax, thoracic circumference, and body weight. The curves are derived from means for Iowa City white males and are drawn to the quarterly values presented in Tables 24 to 27 inclusive.

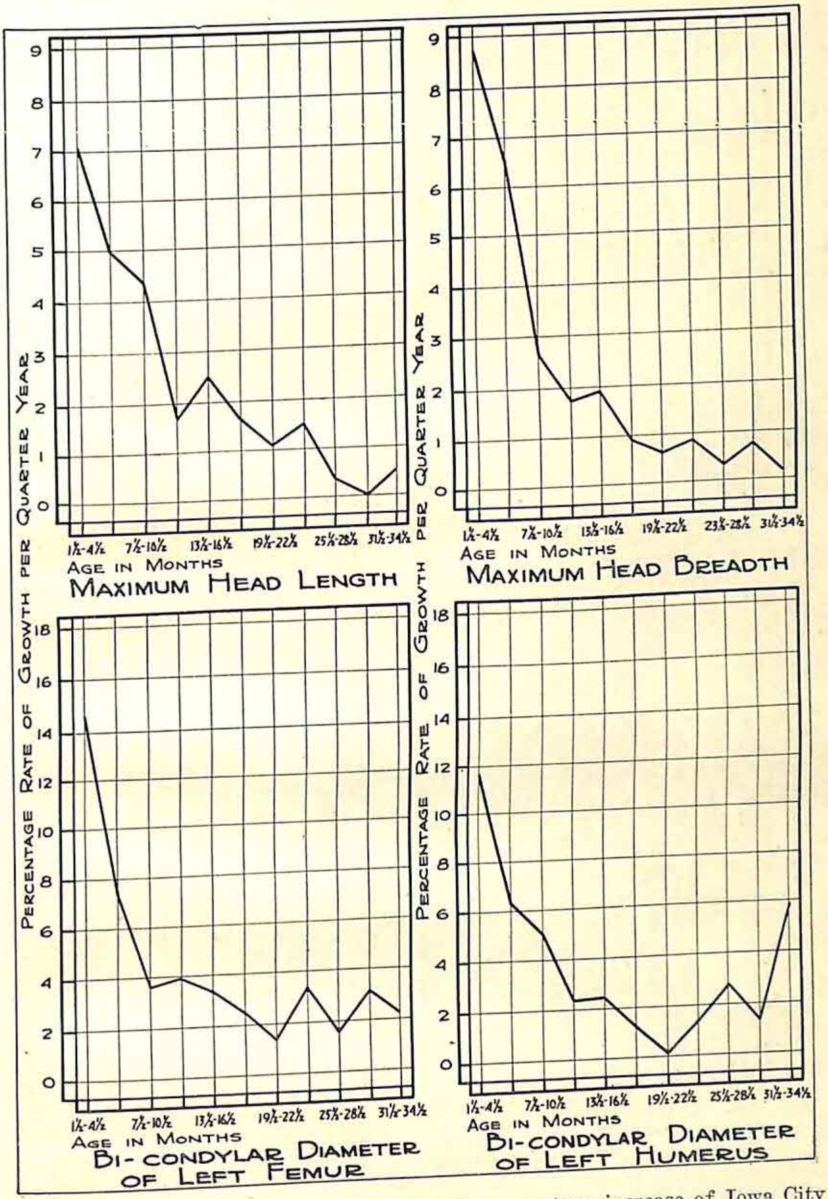


Figure 11. These curves show the quarterly percentage increase of Iowa City white males in maximum head length and breadth and in bi-condylar diameter of left femur and left humerus. The curves are based on the quarterly column of Tables 28 to 31 and cover approximately the first three years of post-natal life.

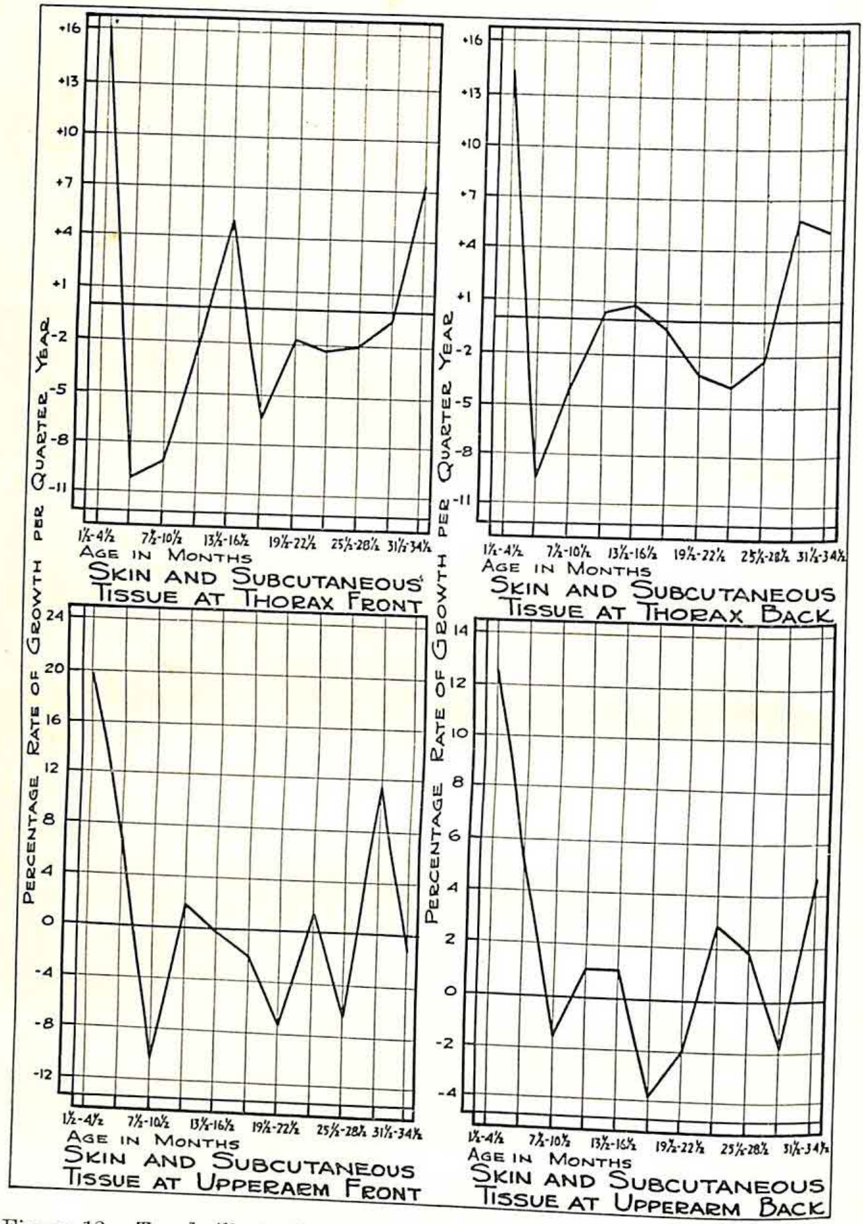


Figure 12. Trends illustrating the relative acceleration-retardation rhythm for four measurements of thickness of skin and subcutaneous tissue are given. The trends are derived from means for Iowa City white males and are drawn to the four series of "quarterly percentage rate" values given in Tables 34 to 37.

Examination of the graphs reveals the following findings:

1. The sixteen curves have one characteristic in common: all make a rapid initial descent. The steepness of this descent is indicated by a contrast of the rate values for the first and second quarterly intervals. During the quarter year interval from 1½-4½ months the mean percentage increment is, approximately, 78 per cent for body weight, 18 per cent for stature and bi-trochanteric diameter, 14.5 per cent for bi-condylar diameter of left femur and for skin and subcutaneous tissue at thorax back, and 9 per cent for maximum head breadth and antero-posterior diameter of the thorax. The mean growth for this selected series of measurements falls during the succeeding quarter year (4½-7½ months) to 19 per cent for body weight, 8 per cent for stature and bi-trochanteric diameter, 7 per cent for bi-condylar diameter of femur and maximum head breadth, 4 per cent for antero-posterior diameter of thorax, and —10 per cent for skin and subcutaneous tissue at thorax back.

2. Nine of the curves are similar in form between 22½-25½ months and 31½-34½ months. That is, the curves for stature, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse diameter of thorax, bi-condylar diameter of femur, maximum head breadth, skin and subcutaneous tissue at upperarm front, and body weight indicate a fall in mean percentage rate of growth from 22½-25½ months to 25½-28½ months, a rise in mean rate for the following quarter year, and a decline in percentage growth from 28½-31½ to 31½-34½ months. Section A of Figure 13 graphically "spots" this three phase segment for each of the nine measurements.

3. The curves for stature, sitting height, bi-trochanteric diameter, and body weight are of the same general form between 4½-7½ and 19½-22½ months. Each is characterized by a continual reduction in mean rate from 4½-7½ to 13½-16½ months, an increase in percentage gain for the quarter year 16½-19½ months and a decrease in relative growth rate for the remaining quarterly interval. (See Section B of Figure 13.)

4. The curves for maximum head breadth, maximum head length, bi-condylar diameter of femur, bi-condylar diameter of humerus, and for skin and subcutaneous tissue at upperarm front follow a like course from 13½-16½ to 22½-25½ months. There is a descent in rate for the first two quarterly intervals and an

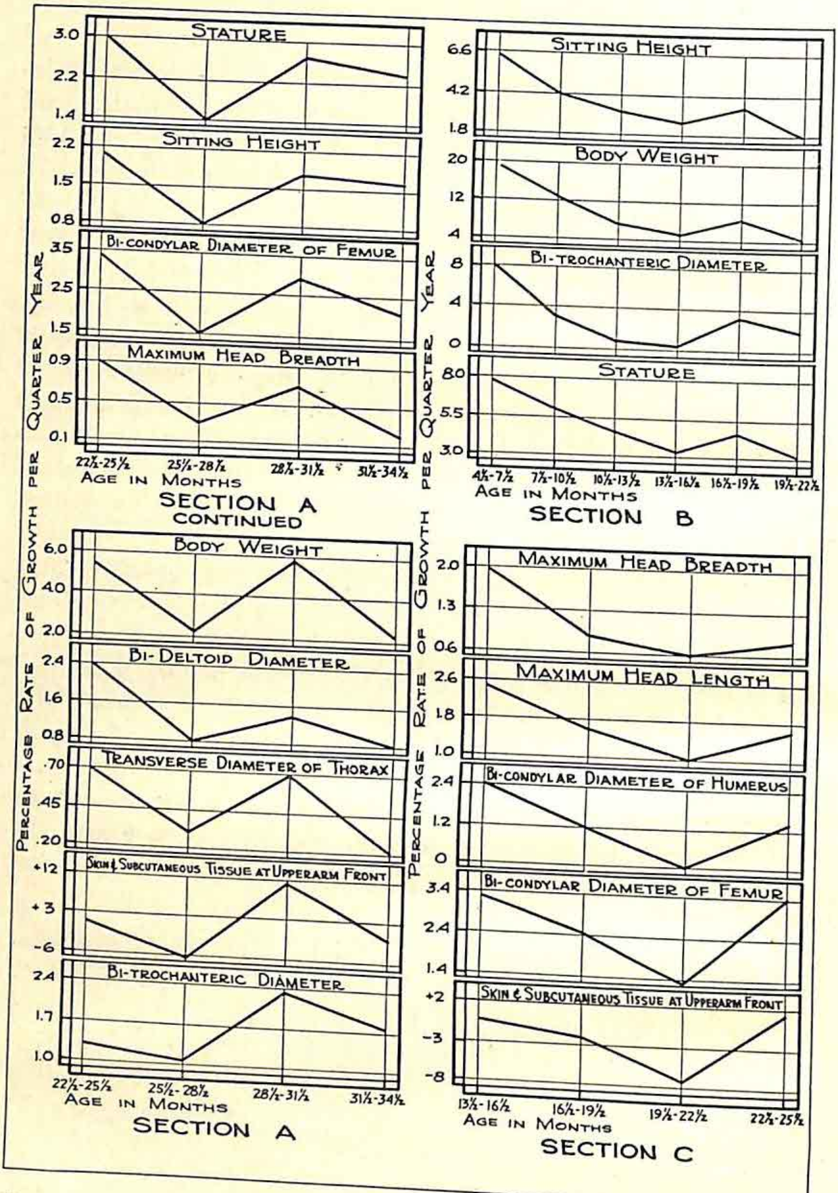


Figure 13. Segments of nine curves having a similar form are shown in Section A of this graph. Sections B and C show segments of four curves and five curves, respectively, which follow like trends. Each segment represents relative rate analysis of consecutive quarterly means obtained from measurement of Iowa City white males.

ascent for the quarter year 22½-25½ months. This is shown by Figure 13, Section C.

5. The curves for maximum head breadth and maximum head length are almost identical in form from 1½-4½ months until 25½-28½ months. Both show maxima at 1½-4½, 13½-16½, and 23½-25½ months; both show minima at 10½-13½ and 19½-22½ months.

6. The curves of bi-condylar diameter of femur and of skin and subcutaneous tissue at upperarm front show corresponding maxima and minima throughout. Each has maxima at 1½-4½, 10½-13½, 19½-22½, and 28½-31½ months. Minima occur at 7½-10½, 19½-22½, 25½-28½, and 31½-34½ months.

7. The curves for skin and subcutaneous tissue measurement at thorax front and back and at upperarm back have a maximum at 13½-16½ months. The thorax front and back curves are characterized by a minimum at 4½-7½ months. The curves for upperarm front and back show a corresponding minimum at 7½-10½ months and, in addition, have a maximum in common at 22½-25½ months.

ANNUAL PERCENTAGE RATE CURVES

The technique used in analysis of percentage increments and decrements expressed in annual terms parallels that employed in the previous section. Figures 14 to 22 afford graphic presentation of the annual percentage rate values itemized in the lower two-thirds of column four, Tables 20 to 37. A separate acceleration-retardation curve, covering the age period from thirty-four and one-half months to eighteen years, is given for each measurement. In all there are percentage rate trends for eighteen physical measurements on Iowa City white males.

The findings, as arrived at by inspection of the graphs, are enumerated below:

1. A primary minimum in mean rate of growth occurs at 5¾-6¼ years for head breadth, head length, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse diameter of thorax, skin and subcutaneous tissue at upperarm front, at thorax front, and at thorax back. The curves for stature and for skin and subcutaneous tissue at upperarm back show a secondary deflexure at this point. An analogous "low" is reached at 5¼-5¾ years in strength of grip, body weight, and bi-condylar diameter of femur; at 4¾-5¼ in thoracic circumference; and at 4¼-4¾ years in antero-posterior diameter of thorax.

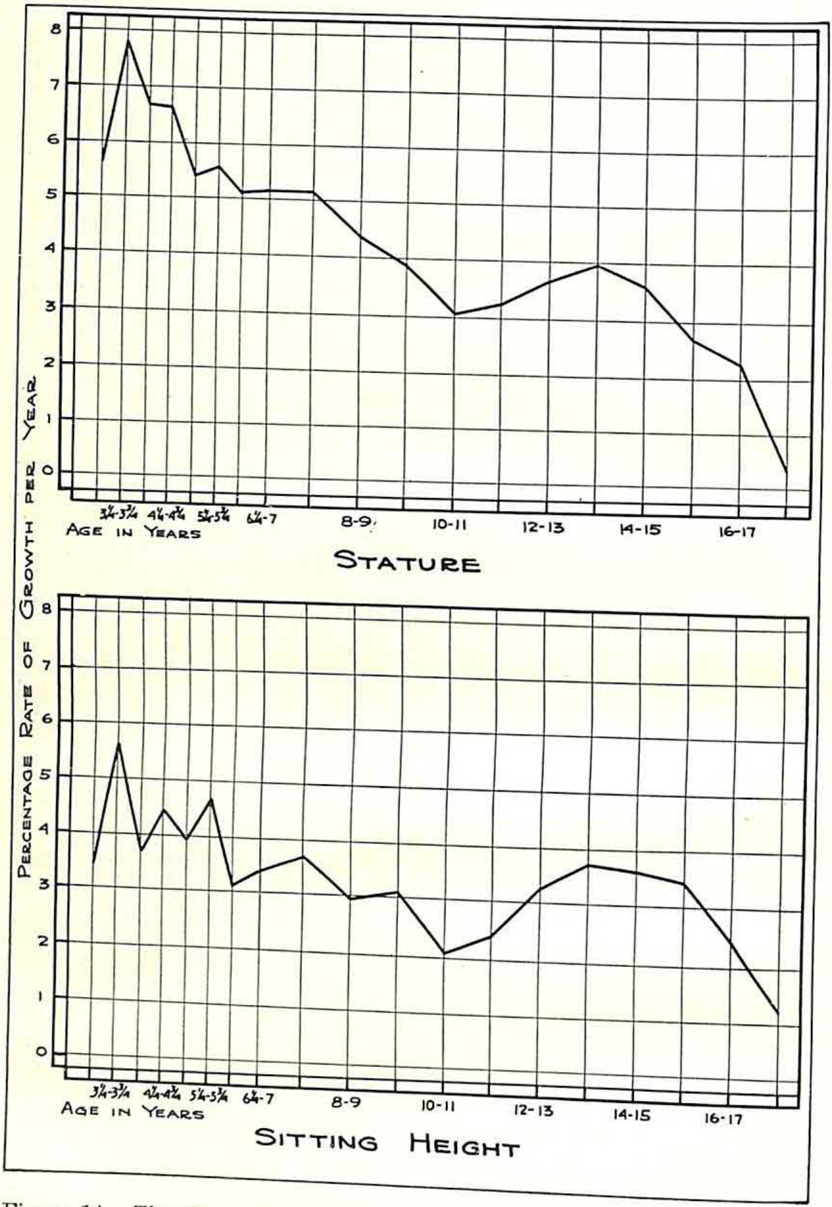


Figure 14. The above curves show the annual rate of percentage increase for two anthropometric dimensions on Iowa City white males over the age period from three to eighteen years. The curve for stature is drawn to the lower nineteen annual increment rates given in Table 20. The sitting height trend is plotted to the corresponding series of values from Table 21.

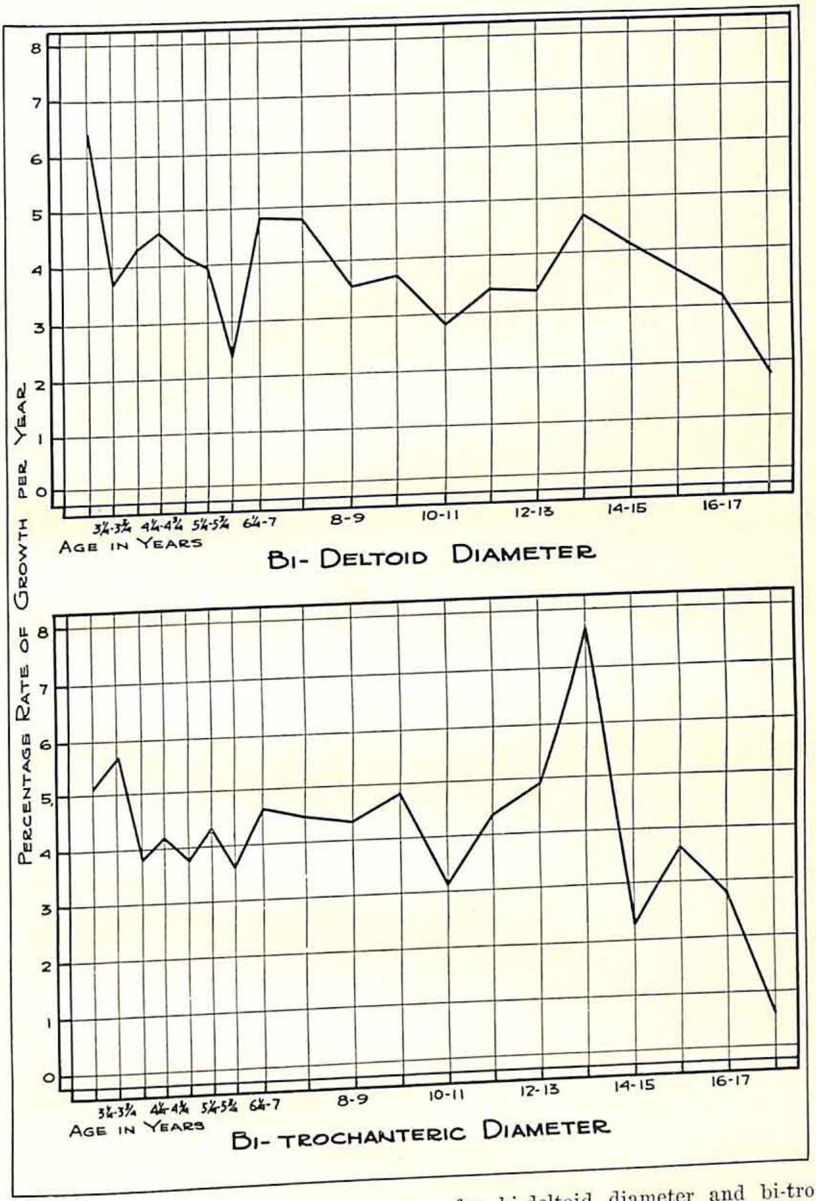


Figure 15. Relative acceleration curves for bi-deltoid diameter and bi-trochanteric diameter are shown. The curves are derived from means for Iowa City white males and are based on annual rate of percentage increment values found in Tables 22 and 23.

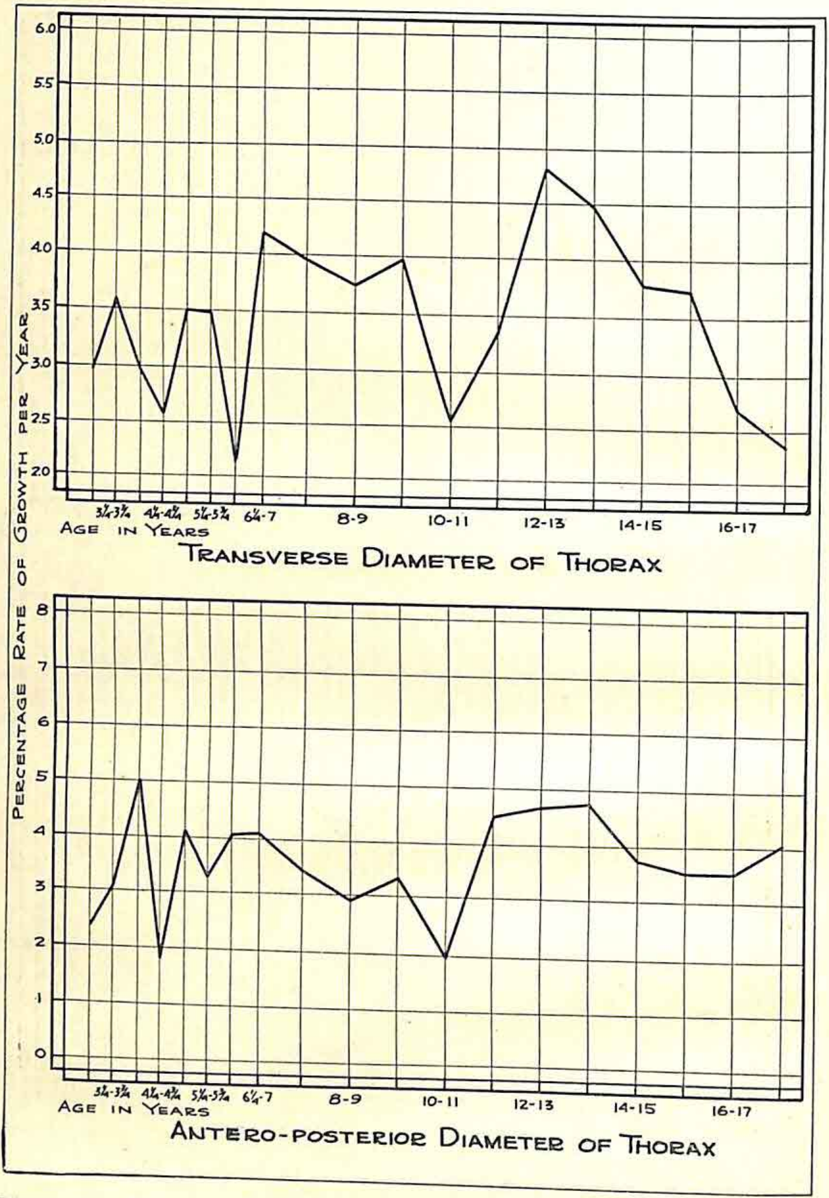


Figure 16. These trends illustrate the mean increment, in per cent per year, of Iowa City white males in transverse and antero-posterior diameters of the thorax. The trends are drawn to the two series of annual percentage rates, for the age range from three to eighteen years, given in Tables 24 and 25.

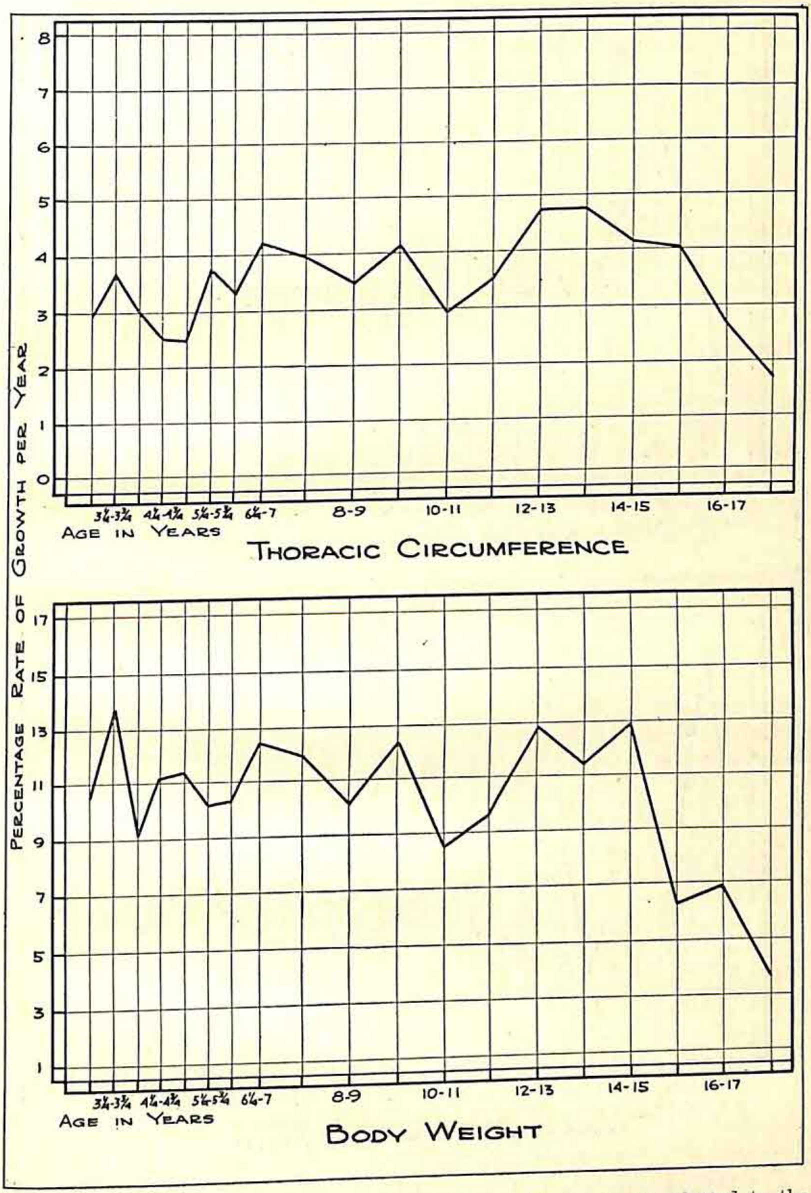


Figure 17. Thoracic circumference and body weight curves are plotted to the lower nineteen annual percentage growth rates presented in Tables 26 and 27. Each curve represents "percentage rate" analysis, using Minot's formula, of a succession of means obtained from measurement of Iowa City white males.

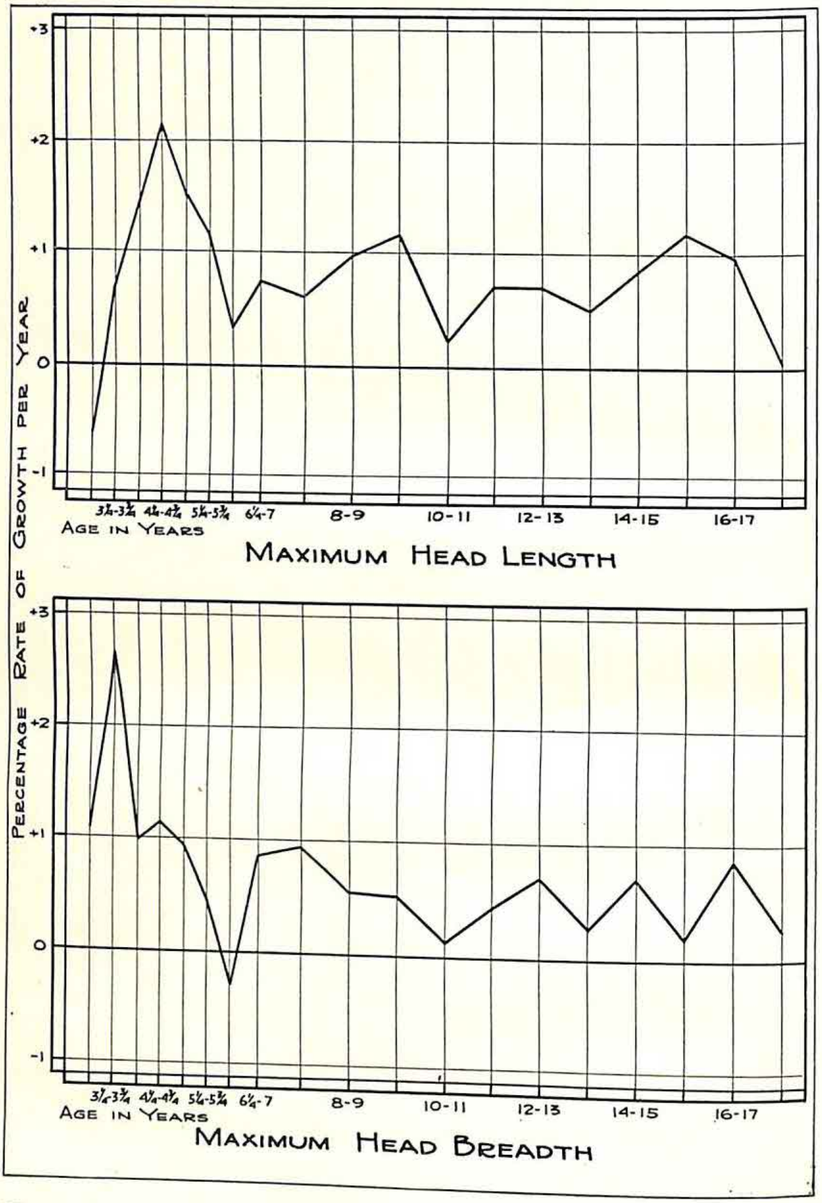


Figure 18. Relative velocity trends for maximum head length and maximum head breadth on Iowa City white males are given. The trends extend over the postnatal years from three to eighteen and are drawn to the annual rate of percentage increment values given in Tables 28 and 29.

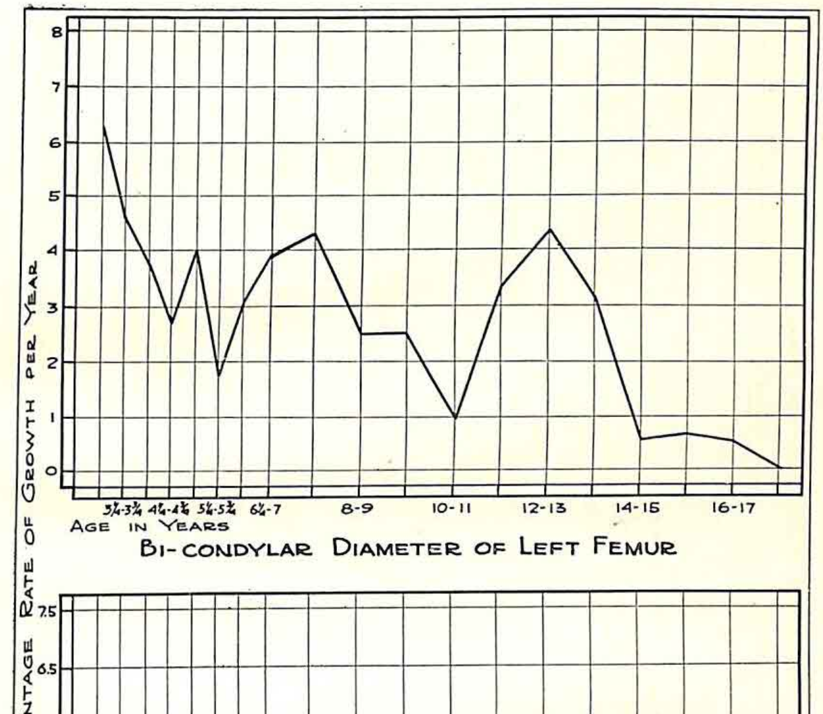
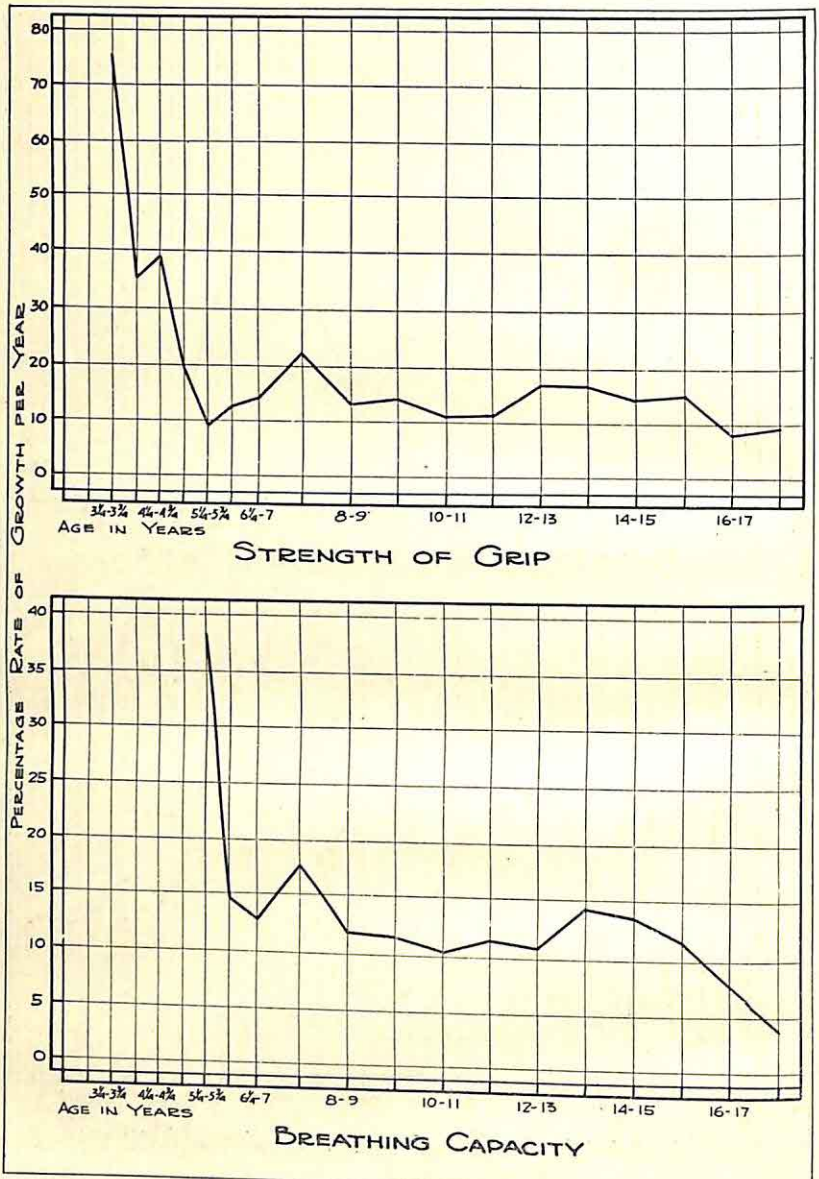


Figure 19. These curves show the annual rate of percentage gain for bi-condylar diameter of the left femur and bi-condylar diameter of left humerus. The curves are derived from means for Iowa City white males and are plotted to annual increment rates presented in Tables 30 and 31.



STRENGTH OF GRIP

BREATHING CAPACITY

Figure 20. The above trends illustrate the mean increment, in per cent per year, of Iowa City white males in strength of grip and breathing capacity. The trends are drawn to the two series of annual percentage rates given in Tables 32 and 33 respectively.

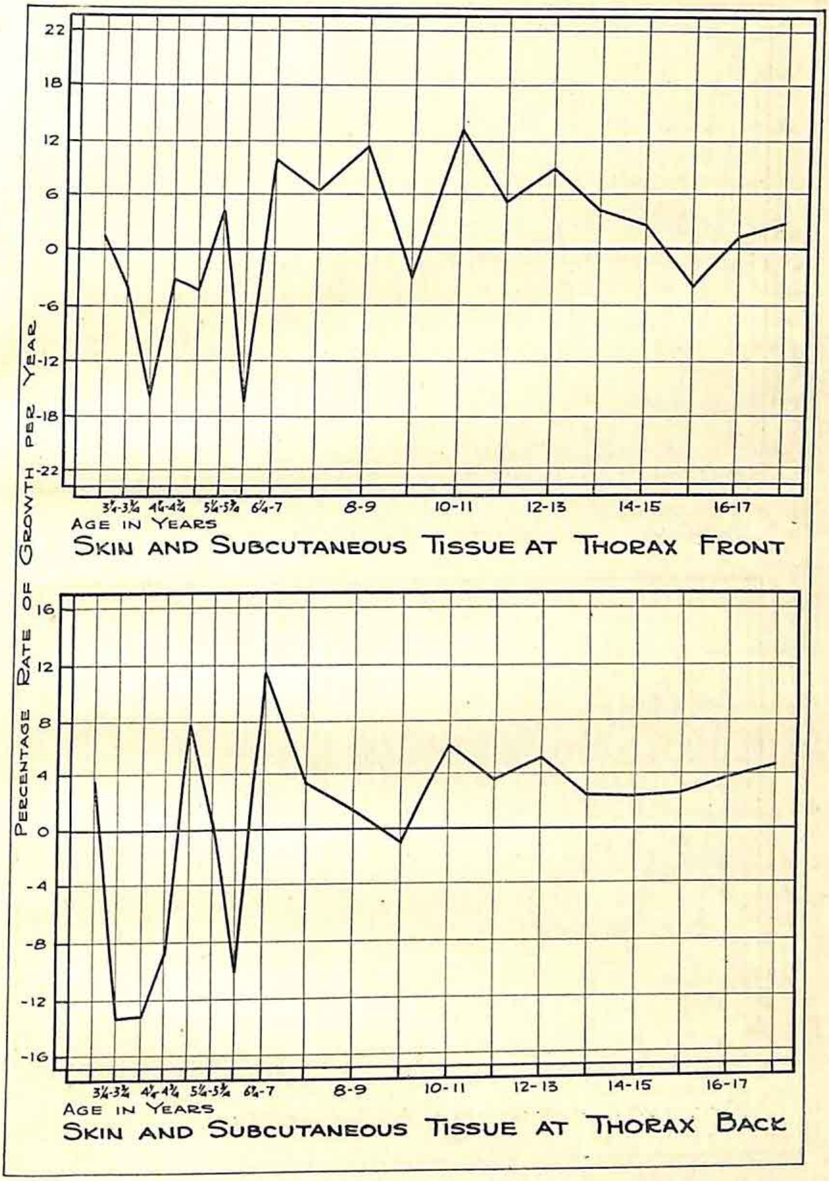


Figure 21. These curves portray the relative acceleration-retardation rhythm, from three to eighteen years, for thickness of skin and subcutaneous tissue at thorax front and thorax back. The curves are derived from means for Iowa City white males and are plotted to annual percentage rate values found in Tables 34 and 35.

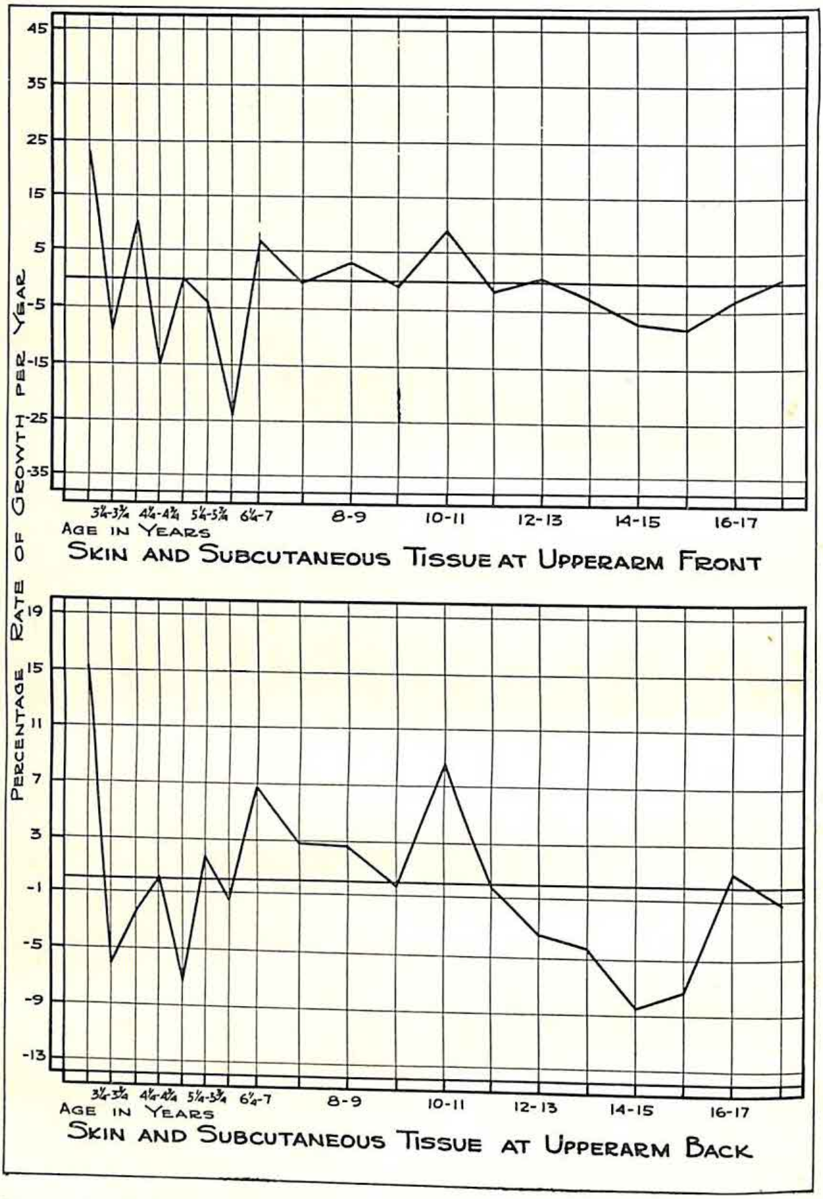


Figure 22. Relative increment-decrement trends are given for thickness of skin and subcutaneous tissue at upperarm front and back on Iowa City white males. The trends extend over the age period from three to eighteen years and are drawn to the lower nineteen annual percentage growth rates presented in Tables 36 and 37.

2. The curves for transverse diameter of thorax, thoracic circumference, body weight, bi-trochanteric diameter, bi-deltoid diameter, and antero-posterior diameter show maxima at 6¼-7 and 9-10 years. The 9-10 years peak is a secondary maxima of the curves for bi-deltoid diameter and antero-posterior diameter of thorax. A maximum at 6¼-7 years also characterizes the curves for all four measurements of skin and subcutaneous tissue. Sitting height, bi-condylar diameter of femur, strength of grip, and breathing capacity trends show a maximum during the succeeding year (7-8).

3. Major minima at 10-11 years and at 17-18 years are found in the curves for stature, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse diameter of thorax, thoracic circumference, body weight, bi-condylar diameter of femur, and breathing capacity. The trends for strength of grip, bi-condylar diameter of humerus, and antero-posterior diameter of thorax show minima at 10-11 years and 16-17 years. All twelve curves reach a maximum at 12-13 or 13-14 years.

4. The curves for maximum head length and breadth have minima in common at 5¾-6¼, 10-11, and 17-18 years. They are dissimilar, however, with reference to maxima. The head breadth trend is characterized by maxima at 4¼-4¾, 9-10, and 15-16 years; the head length trend has maxima at 3¼-3¾, 7-8, and at alternate years from 12-13 forward. The fluctuations in the latter curve beyond 12-13 years probably do not represent biological reality. It should be recognized that growth in head dimensions is slight during these years, and consequently percentage rate curves are necessarily derived from small differences in mean magnitude. In general, the curves appear surprisingly regular. Particularly interesting is the marked depression in rate at 10-11 years which both measurements have in common with the twelve measurements discussed in the second of these findings.

5. The curves for the four measurements of skin and subcutaneous tissue show maxima in common at 6¼-7, 10-11, and 17-18 years (16-17 in one instance). Common minima occur at 5¾-6¼, 9-10, and around 14-15 years. The curves for thorax back, upperarm front, and upperarm back fall abruptly at 3¼-3¾ years. Thorax front, thorax back, and upperarm front have a secondary peak at 12-13 years.

The most impressive single finding is the mean decrease in growth rate during the 10-11 years. This is common to every measurement analyzed but those for skin and subcutaneous tissue. Hardly less striking is the "high" in percentage rate found during this year interval for the latter measurements. Figure 23 contrasts the percentage growth at annual intervals from 8-9 to 11-12 years for a series of measurements of each type. The directly opposite trend of the four measurements of skin and subcutaneous tissue on the one hand and of six general body dimensions on the other is evident and well-marked.

It appears reasonable that during the "low" in general bodily growth from age ten to eleven years there should be an increased deposit of subcutaneous fat. Likewise, it does not seem far-fetched to expect that, with the beginning of the preadolescent increase in the rates of growth for most physical dimensions, this stored fat should be drawn upon. These deductions, of course, are intended to be read as suggestive comment, not as rigorous explanation.

GENERALIZED PERCENTAGE RATE CURVES

The analysis made in the preceding two sections may best be epitomized and given perspective through the medium of a few generalized or semischematic curves. Four such curves are presented in Figure 24.

The values to which these curves are drawn were obtained from smoothed trends. The entire series of annual percentage rates for each measurement was plotted on a graph twenty-four by eighteen inches and the point-to-point curve subjected to free-hand smoothing.

All four curves make an initial steep descent indicative of the very rapid decline in rate of growth during the first year. Beyond this age the lines diverge and each is characterized by at least one unique feature.

The curve for bi-condylar diameter of femur continues downward but in a less abrupt manner until 5-6 years. Thereafter it describes two convex arcs—one extending from 5-6 to 10-11 years and the other from 10-11 to 17-18 years. The latter is positively skewed since mean growth in this dimension is slight after fifteen years.

The trend for sitting height descends somewhat more rapidly than the one for femur until about 2-3 years. Between 3-4 and 5-6 years it exhibits an almost constant growth rate. There is a decline at 6-7 years followed by two convex arcs which span the age periods from 6-7 to 10-11 years and from 10-11 to 17-18 years.

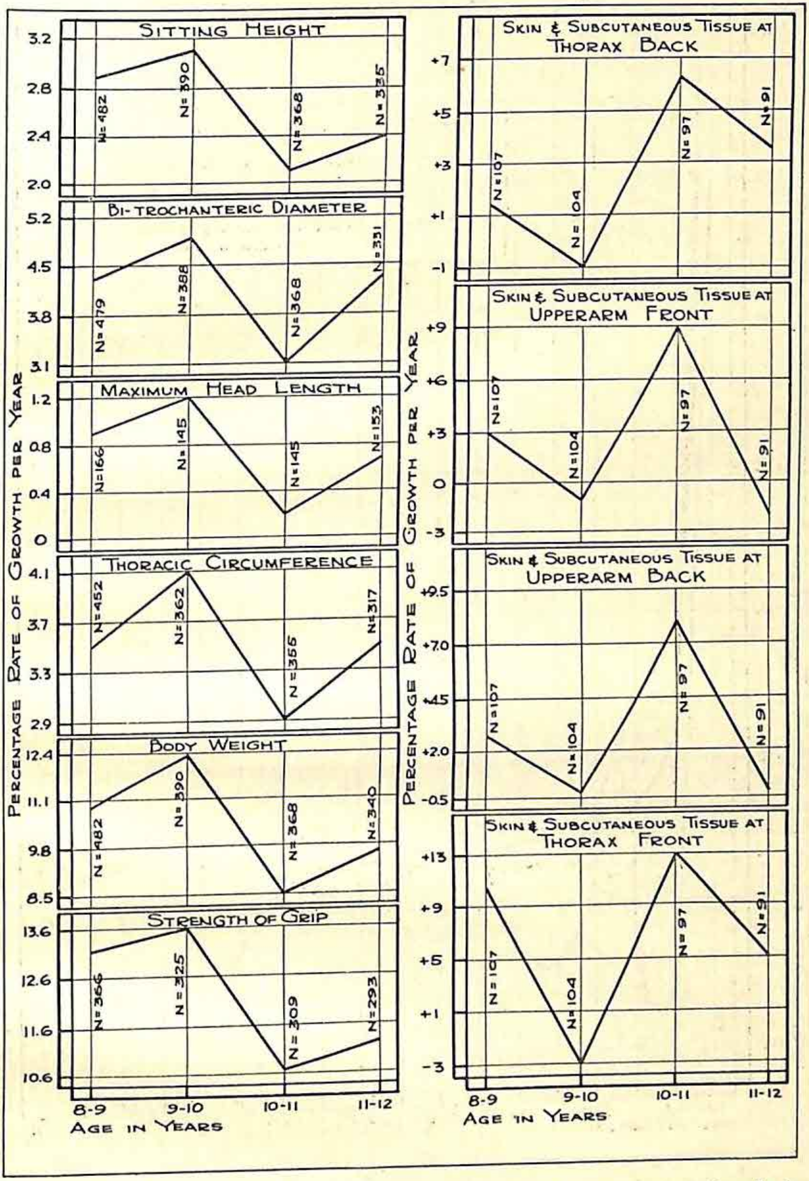


Figure 23. The left panel of this graph shows analogous segments of six annual "percentage rate" curves for diverse anthropometric measurements on Iowa City white males. Comparable segments from annual "percentage rate" curves for four measurements of skin and subcutaneous tissue are presented in the right panel. The directly opposite course of the segment trends in each panel is clearly portrayed.

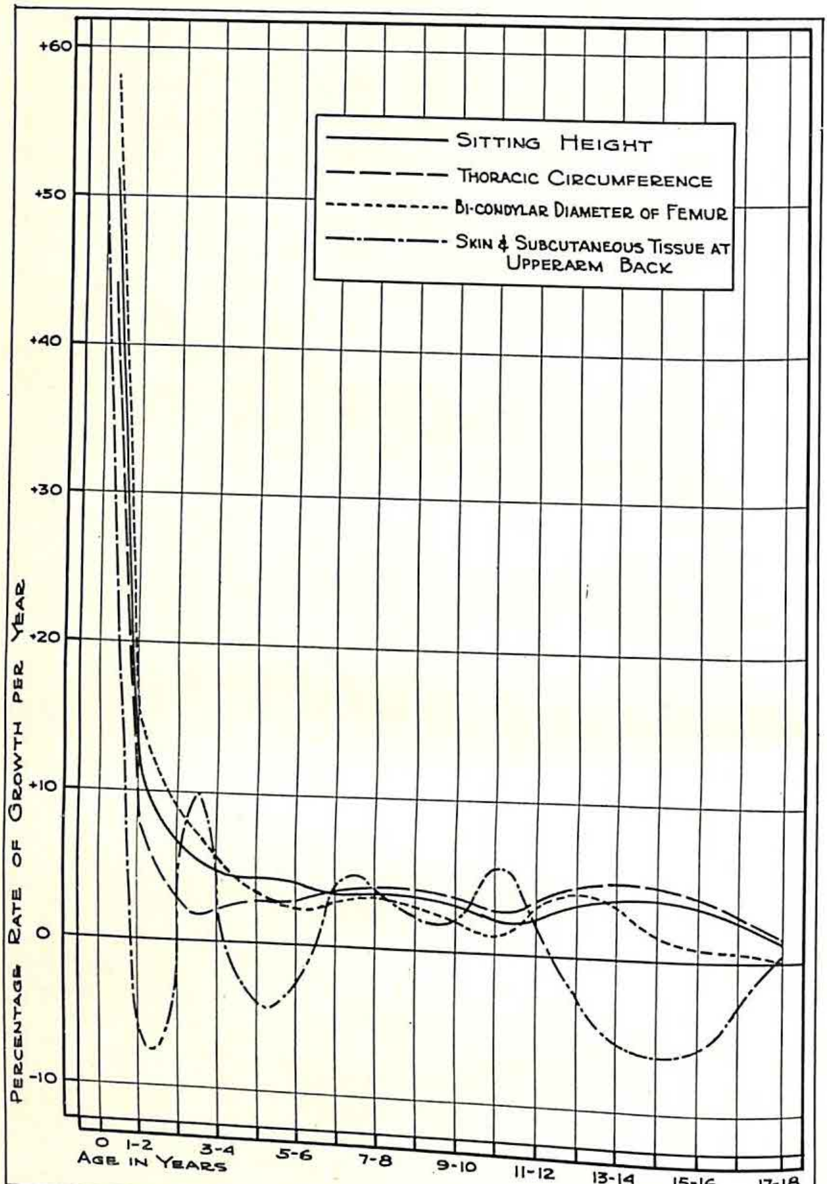


Figure 24. A series of semischematic curves illustrate general forms of the relative velocity rhythm for Iowa City white males. The trends represent the first eighteen years of postnatal growth in sitting height, thoracic circumference, bi-condylar diameter of femur, and skin and subcutaneous tissue at upperarm back.

The curve for thoracic circumference descends sharply from 1-2 years to reach a minimum about three years. It then rises again until around four years. Between 5-6 and 10-11 years it parallels the arc described by bi-condylar diameter of femur, whereas between 10-11 and 17-18 years it follows the course of the arc described by sitting height.

The trend for skin and subcutaneous tissue at upperarm back fluctuates considerably above and below the curves for the general bodily measurements. It has primary minima at approximately two, five, and fifteen years and maxima at three, seven, 10-11, and 17-18 years. The tendency for percentage rate curves of skin and subcutaneous tissue to counterbalance like curves for general bodily measurements over certain age periods is again indicated. From 10-11 to 17-18 years the upperarm back curve describes a decidedly concave rather than convex arc. The abrupt rise at about three years, offsetting the fall in the trend for thoracic circumference, is also suggestive.

CHAPTER IV

GROWTH OF THE INDIVIDUAL

There are two approaches to an analysis of the growth rhythm for any bodily dimension. Attention has thus far been confined to the generic or collective approach. This chapter will supplement the generic picture with a few findings from the specific or individual approach.

GENERAL FORM OF INDIVIDUAL CURVES

Scammon (18) has compared an individual height curve with a mean curve for the same linear dimension. He finds that "the general form of the curve is essentially the same in both instances" but points out that "The prepuberal increase in height of the individual is a little more abrupt than that of the group. . . ." (18, p. 335) The generalized curve used in making the comparison is based on annual means for a French population; the seriatim curve is drawn to semiannual height measurements for a single (French) white male. The latter covers the age period from birth to eighteen years and is described as showing

> ". . . a period of rapid growth during infancy and early childhood; a middle period, extending from three to nearly thirteen years, in which growth is slow but constant; a marked period of prepuberal acceleration, from about thirteen and one-half to fifteen years, and a period of slow terminal increment thereafter." (18, p. 331)

Individual curves for the growth of four brothers in body weight are also afforded by Scammon (21, p. 181-183). These curves extend over the age period from birth to twenty years and are drawn to year-by-year ponderal values obtained by Professor Martin Guttmann of Vienna. They are considered to follow the same "double sigmoid course" as the height curve except for "some accentuation of the points of inflection of the progression and a more marked increase in the rate of growth in the years preceding puberty." (21, p. 181) Inspection of the trends confirms the implication of this last phrase, namely, that individual weight curves for white males tend toward concavity during the childhood years.

Unfortunately, the data of the present investigation do not include seriatim observations for any measurement over the full age period from birth to eighteen years. The longest individual records extend from approximately five to eighteen years. Figure 25 gives six individual trend lines for stature and a like number for bi-trochanteric diameter over this thirteen-year age span. The stature curves were selected to represent six diverse height levels at nine years of age. The bi-trochanteric diameter curves are for the same individuals as the stature trends. Examination of the figure yields the following observations:

1. The individual stature curves are of the same general form as the mean curve for stature.
2. Each of the six specific stature trends has a greater sharpness and steepness to its major inflection than is shown by the mean curve.
3. The major inflection is less marked in the mean trend because it is timed variously in the individual stature sequences. The beginning of the rapid incline in the six individual curves ranges over a period of four and one-half years—from about eleven to fifteen and one-half years of age.
4. The individual trends for bi-trochanteric diameter fluctuate too frequently to allow meaningful comparison with the mean curve for this physical dimension.

It appears appropriate to cite a series of approximately eighty individual growth curves for white males presented by Baldwin (1). These curves include trends for stature, sitting height, body weight, thoracic circumference, and breathing capacity. They extend over the age interval from six to eighteen years. The individual curves for stature and sitting height most consistently parallel their corresponding mean trends in general form. The curves for the other three measurements are considerably more irregular.

With reference to the period from six to eighteen years, it appears that, in general, individual curves for bi-trochanteric diameter, thoracic circumference, body weight, and breathing capacity may be considered in only a crude sense, if at all, to show the form of their respective mean curves. On the other hand, individual trends for stature appear to follow essentially the same general form as the mean curve for stature.

The generalization that individual stature curves are of the same general form as the mean curve between six and eighteen years requires further support since it is challenged by at least one major

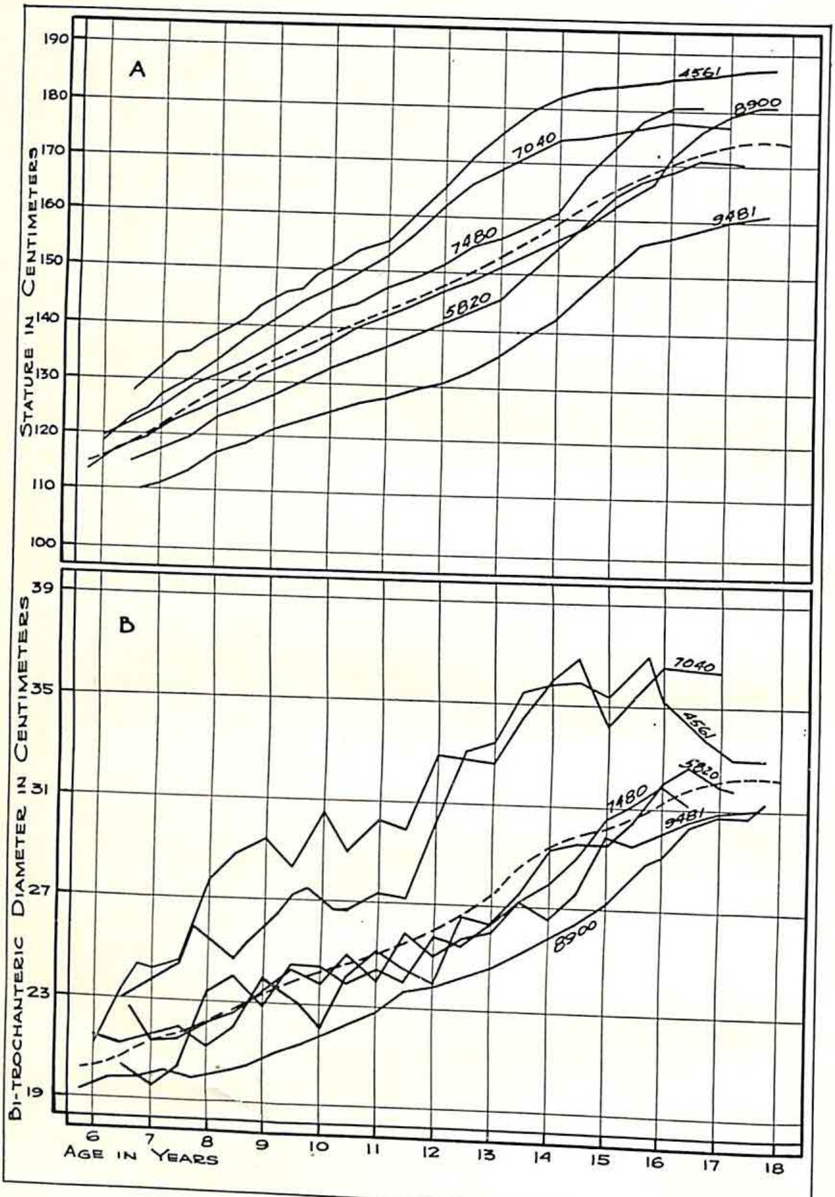


Figure 25. Section A of this graph gives six individual stature trends for Iowa City white males. The trends extend from six to eighteen years and are selected to represent diverse stature levels at nine years of age. Curves for bi-trochanteric diameter on the same six individuals are presented in Section B of the graph. In general, the twelve curves are plotted to semiannual measurement values.

study. Baldwin, to be specific, reports two forms of individual stature curve during these years. He writes:

> "If the increments of growth in stature before adolescence are relatively uniform (i.e. represented by a straight line on the charts) this uniformity in increase tends to persist throughout adolescence. If there is retardation before adolescence the tendency is to show a rapid acceleration during adolescence, as a compensating factor." (1, p. 92)

Two questions follow from this statement: (1) Do the data of the present study reveal these two types of curve? (2) If so, what proportion of Iowa City white males show the "acceleration" type and what proportion the "uniform" or linear form?

To answer these questions individual curves for growth in stature were constructed for fifty white males. No criterion of selection was used other than availability. All records were graphed that furnished seriatim measurements for the necessary number of years. For the most part the records afforded measurement values at semiannual intervals.

The fifty indvidual curves[3] were independently analyzed by the writer and by Dr. Helen L. Dawson, research associate in anthropometry, of the Iowa Child Welfare Research Station. The method of classification used was that suggested and apparently used by Baldwin, that is, departure or nondeparture from a rectilinear trend. Forty-eight of the fifty curves were found to show unequivocal acceleration. One of the remaining curves was considered to show slight acceleration; the other was characterized by fluctuations which made clean-cut classification impossible.

While much depends on the connotation which Baldwin intended should be given to the phrases "relatively uniform" and "rapid acceleration," the present sampling shows the acceleration form of curve to be typical. A conservative conclusion is that, if the linear form of individual stature curve is to be found for Iowa City white males, it probably is not common to more than 4 or 5 per cent of these males. Thus it appears justifiable to conclude that for these males between six and eighteen years, the individual stature trends are of the same general form as the mean curve.

PREDICTION OF STATURE BETWEEN SIX AND ELEVEN YEARS

Stature is selected since it furnishes data which give sufficiently regular individual curves to reveal the possibilities of prediction.

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[3] Eighteen of these curves are given in Figures 25, Section A, and 26. Wherever possible the curves were plotted for the period from six to eighteen years.

Successive measurement values for other dimensions (at least for those discussed above) appear less suitable for use in experimental attempts at the prediction of individual physical growth.

Courtis Method of Prediction

The first method of prediction that will be considered is one that has been enthusiastically propounded by Professor Stuart A. Courtis of the University of Michigan during the last eight years or more (4, p. 3). Courtis is convinced that he has discovered a universal law which may be used to predict specific or individual biologic growth. On the theoretical side, the method has been ably clarified and developed. A much abridged description will suffice here. Growth is defined as

> ". . . the progress toward maturity made by an immature organism acted upon by constant nurture under constant conditions." (5, p. 488)

Prediction, according to Courtis,

> ". . . does not refer *at all* to an attempt to foretell how long the situation *will remain* constant. Science deals only with the attempt to describe in advance of its occurrence, what course growth will follow." (5, p. 488)

These concepts of growth and prediction have diagnostic implications since marked deviations from predicted values indicate the entrance of new and disturbing factors into the growth situation.

The "universal law" for the prediction of growth is that

> ". . . the increases in the loglogs of the percentages of maturity are directly proportional to the increases in time." (5, p. 488)

This so-called biologic law is derived from the exponential formula

$$y = ki^{r^t}$$

in which y is the magnitude attained at time t, k is the maximum magnitude or value at maturity, i is the initial value or degree of development attained at the beginning of the growth period, and r is the rate of growth per unit of time. The equation is that of a modified S-curve known as the Gompertz trend. Its distinguishing characteristic lies in the fact that

> "In this trend the point of inflection, where the positive curve changes from concave to convex, is at 37% of the maximum height ($1/e = 1/2.71828 = 0.36788$." (7, p. 168)

It follows that two assumptions are made when the Gompertz formula is used to describe and predict growth. First, it is assumed that

> ". . . all growth curves are identical in form and differ only in the length of the period of maturation." (4, p. 3)

Secondly, the assumption is made that 50 per cent of the magnitude at maturity is always attained at the termination of 37 per cent of the growth period.

Referring back to the "law of growth" itself, it is now apparent (1) that raw measurements are reduced to "percentages of maturity" in order to convert them from absolute units into relative or pure units and (2) that loglog values are used for the purpose of translating the exponential equation into a simple linear equation.

Finally, to facilitate computations, the time axis of the curve is divided into 100 equal parts called isochrons. An isochron may be regarded either as 1 per cent of the total time required for growth or as 1 per cent of the full range of "the loglogs of the percentages of maturity." The name isochron is intended to emphasize that there is a one-to-one relationship between units of time and loglog values.

With the above theoretical background in mind, it is now possible to apply this system to the prediction of stature in Iowa City white males over the period from six to eleven years. Courtis claims that

> ". . . the growth of individual boys and girls in height. . . is a multicycle phenomena." (4, p. 120)

That is, the rhythm of growth for human stature is considered to consist of several overlapping growth curves of the Gompertz form. One of these curves is found to reach its maximum at about six years of age and another to extend between this age and the twelfth year. To quote directly, Courtis writes,

> ". . . I know in general that a new cycle of growth [in height] starts about six years and a second one about twelve years, plus or minus three years in each case. . ." (6, p. 5)

The problem which emerges now is that of finding specific values of i and k for this cycle. Only when magnitudes for any given individual at the beginning and at the end of the cycle are obtained can one determine the "percentages of maturity" that he should attain at each intermediate interval of time. The values of i and k may be found by formulae (1) "given three reliably determined points anywhere on the growth curve'' (5, p. 489) and (2) provided that these points are "a sufficient distance apart to give substantial differences between measurements.'' (6, p. 4) These two conditions, however, are difficult to meet.

First, one can never be certain that he has three measurement values which are definitely on the curve. The six and twelve year limits are each qualified by three years in either direction. This means that in any specific case there is no assurance that even one point is on the curve. Points occurring before nine years may belong to the preceding curve; points after nine may be on the succeeding cycle. Nor does inspection of the curves help. If the two cycles which are supposed to overlap around six years exist at all, they overlap so completely that it is impossible by inspection to make a reasonable conjecture as to where the six-to-twelve-year curve begins its relay of the growth rhythm. The use of inspection at the upper end of the cycle is, of course, out of the question since if this portion of the cycle is given nothing remains to be predicted.

Secondly, when points are secured "a sufficient distance apart,'' there is little if any of the cycle left to predict. A specific example will illustrate this. From stature measurements on an Iowa City white male at approximately eight, nine, and ten years a *k* value of 182.6 was obtained. The actual stature of this boy at twelve years was near 152 cm. In evaluating the excessive maximum magnitude secured for the six-to-twelve-year cycle in this instance, Courtis writes,

> ". . . a year means a different interval in each curve and when three measurements occur as near each other as these three do, the heights must be determined reliably to within a *mm.* to make prediction safe.'' (6, p. 7)

Besides pointing out that time intervals of one year are considered to be "near each other'' for this cycle, this statement makes the transition to the matter of reliability of the measurements. Again Courtis writes:

> "The growth formula is an exponential formula. Very small errors in the early part of the curve produce very large errors in the maxima. . . In height. . . measurements unreliabilities of .6 cm. . . are common. Such errors in measurements occurring early in the curve and separated by small time intervals, make the attempt to predict maxima of questionable value.'' (6, p. 3)

The following tabulation presents the *k* values, as calculated by formula, for the six-to-twelve-year cycle of the six individual curves of stature given in Section A, Figure 25. The cases are listed in the same order as they appear on the graph.

	Three Selected Points			*k* Value	Observed Stature at Twelve Years
Age	7 years, 9 months	8 years, 9 months	9 years, 9 months	191.8	166.0
Stature	136.7	143.0	148.7		
Age	7 years, 9 months	8 years, 9 months	9 years, 9 months	174.3	162.0
Stature	132.4	139.6	145.7		
Age	7 years, 2 months	8 years, 2 months	9 years, 2 months	117.3	151.8
Stature	126.8	131.0	137.2		
Age	7 years, 2 months	8 years, 2 months	9 years, 2 months	179.8	146.0
Stature	121.6	127.0	132.0		
Age	7 years, 3 months	8 years, 3 months	9 years, 3 months	41.9	140.8
Stature	119.4	124.3	129.6		
Age	7 years	8 years	9 years	130.2	132.0
Stature	111.0	117.0	121.2		

Since the method yields results of this type for stature, it is unlikely to be found useful for predicting the growth of the individual in other bodily dimensions.[4]

McCall's T-Scale Technique

The utilization of McCall's T-scale technique furnishes an alternative approach to prediction over the six-to-twelve-year span. (14, Chapter X) That this method may have merit is suggested by a finding for individual curves of stature reported by Baldwin.

> "With both boys and girls the curves assume a railroad appearance; each individual boy and girl holds approximately his or her relative position in the group for the periods from six to 17 years of age, with little crossing of the individual curves." (1, p. 73)

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[4] This evaluation should be understood as applying specifically to the prediciton of human physical growth. The writer has no intention of implying that the method may not be found useful both for prediction in other areas and for the study of other problems in this area.

If this finding is sound for the period from six to twelve years, the T-scale method will yield reasonably accurate predictions. On the other hand, to the extent that the individual Iowa City white male does not hold his "relative position in the group" throughout these years the method will prove inadequate.

T-scores are based on the standard deviation of the distribution and range from zero to 100. The zero point is taken at five standard deviations below the mean and the upper limit at five standard deviations above the mean. Each T unit represents one-tenth standard deviation, and the mean of the distribution falls at the T-score 50.

The method used in constructing the T-scale for the five years, six months to six years, six months distribution for stature is as follows:

1. Computation of the number of males exceeding each class interval
2. Determination of half the frequencies falling in each class interval
3. Calculation of the per cent of males exceeding plus half those reaching each interval
4. Reading of the standard deviation value corresponding to each per cent from Table 23 of McCall's text (14, p. 274-275)
5. Plotting of the T-scores, using equidistant T units for the ordinate scale and class interval mid-points as the abscissa units

The final step makes it possible to obtain readily the T-score equivalent of the measured stature for any six-year-old Iowa City white male.

A similar procedure gives comparable plots based on the stature distributions at eight, nine, ten, and eleven years. The method of prediction is that of determining the T-score corresponding to the stature measurement for a given individual at six years, and then reading from the eight, nine, ten, and eleven year graphs the respective stature measurements which are equivalent to this T-score.[5]

The data of the present study include seriatim stature measurements on a total of forty individuals for the period from six to eleven years of age. Application of the T-score graph method to these forty cases gives a mean error of prediction, disregarding signs, of 0.80 cm. at eight years, 1.05 cm. at nine years, 1.24 cm. at ten years, and 1.49 cm. at eleven years. The largest errors of prediction, as one would expect, occur in estimating stature at eleven years from observed stature at six years. Here the maximum error of prediction is 4.6 cm., and in seven instances the estimated minus the observed stature gives a value in excess of 2.5 cm. Stated in the converse, 82 per cent of the predictions over this five year span are not in error more than 2.5 cm., whereas the mean error for the 82 per cent, disregarding signs, is less than .9 cm.

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[5] The T-score technique is used in preference to the percentile method because it is considered to have the advantage of facilitating computation. The T-score technique affords linear graphs while the percentile method would give ogive plots. Values, particularly those clustering around the mean, are more readily and accurately read from linear trends than from ogive curves.

On the basis of this sampling, it appears that the T-score or the percentile technique furnishes a reasonably refined instrument for predicting the stature of the individual Iowa City white male at eleven years of age from his stature measurement at six years of age.

STATURE CURVES FROM ELEVEN TO EIGHTEEN YEARS

No attempt will be made to predict individual stature at each yearly interval between eleven and eighteen years. Instead, a series of curves will be analyzed with the intention of revealing, at least in part, the nature of the prediction problem during these years. Three topics will receive consideration: (1) the age when marked acceleration in stature begins, (2) the age when maximum adolescent stature is reached, and (3) the constancy of stature rank or position in the group.

The series of individual stature trends is for forty-five Iowa City white males. It represents all available cases on which there are stature measurements throughout the seven year period under discussion.

Age When Marked Acceleration in Stature Begins

That individual curves for stature characteristically take a decided "turn towards the vertical" sometime after the eleventh year was shown early in this chapter. This turn, indicative of a marked acceleration in rate of growth, begins at widely diverse ages in different individuals. Analysis of the forty-five curves described above shows that for eight cases it began during the twelfth year, for ten cases during the thirteenth year, for ten cases during the fourteenth year, for twelve cases during the fifteenth year, and for the remaining five cases during the sixteenth year.

It has been suggested that this five year spread does not make the conditions for prediction as chaotic as they might at first appear since there is a relationship between stature rank and onset of the acceleration. The relationship is expressed by the claim that the acceleration is timed "earlier for tall girls or boys than for those below the norms." (1, p. 92) Two questions immediately arise. Do the forty-five curves of this study confirm the view that the increased rate of growth in stature appears earlier in tall boys than in short ones? If so, what is the age range of beginning acceleration for tall, medium, and short Iowa City white males?

The answer to these questions presupposes criteria by which to determine tallness and shortness. The eleven year standards given in the Baldwin-Wood table on "Range of Height for Short, Medium, and Tall Boys" were taken. These standards are used to analyze the trends of the forty-five boys at eleven years of age; the results are tabulated below:

Stature, Centimeters	Cases	Mean		Range				
		Years	Months	Years	Months		Years	Months
Tall (more than 148.3)	5	11	10	11	0	to	13	11
Medium (136 to 148.3)	35	13	5	11	0	to	15	9
Short (less than 136)	5	14	0	13	0	to	15	1

The tabulation shows that, on the average, there is a tendency for boys who are tall at eleven years of age to enter into their period of accelerated growth earlier than boys who are short at this age. The obtained mean for tall boys is near twelve years, for boys of medium stature approximately thirteen and one-half years, and for short boys fourteen years. The overlapping, however, is considerable. The range for medium boys encompasses that for both tall and short boys.

A tabulation which has bearing on the topic of beginning acceleration and on the topic of constancy of stature rank in the group parallels the one immediately preceding except that stature at eighteen years, rather than at eleven years, is used as the point of reference. Tallness and shortness were determined by means of the eighteen year standards of the Baldwin-Wood table for "Range of Height for Short, Medium, and Tall Boys."

Stature, Centimeters	Cases	Mean		Range				
		Years	Months	Years	Months		Years	Months
Tall (more than 181.3)	6	13	9	11	0	to	15	9
Medium (167.7 to 181.3)	35	13	3	11	0	to	15	4
Short (less than 167.7)	4	13	4	11	6	to	15	1

Obviously, the figures indicate that there is no appreciable difference between the tall group of boys at eighteen years and the short group of boys at this age either in regard to the average time of onset of the acceleration or with reference to the range of years over which the onset occurs.

Age When Maximum Adolescent Stature is Reached

As a prerequisite to the treatment of this topic, it is necessary to define what is meant by "maximum adolescent stature." Preliminary examination of the forty-five curves showed that increase in stature usually takes place until the seventeenth or eighteenth year. However, it was observed that some individuals approach this maximum very differently from other individuals. For example, Section C of Figure 26 shows two individuals who attain approximately the same maximum, yet one (case 9164) is within two centimeters of this maximum at fourteen years of age, while the other (case 4241) is seventeen and one-half years of age before he reaches the two centimeter zone. To allow for this factor of small plateau changes, it was arbitrarily decided to read all values at three centimeters below the maximum[6] attained at eighteen years. "Maximum adolescent stature" is thus defined as the stature at eighteen years minus three centimeters.

The analysis procedure will be the same as that used with the topic of beginning acceleration.

For the forty-five cases as a whole the boundary limits of the period when maximum adolescent stature is reached are found to be over four years apart. In one instance adolescent growth is terminated during the last quarter of the fourteenth year. For four individuals maximum adolescent stature is attained during the fifteenth year; for fifteen, twenty, and five individuals it is reached during the sixteenth, seventeenth, and eighteenth years, respectively.

Analysis in terms of the three stature groups, again using eleven years and eighteen years as the points of reference, gives the following tabulation:

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[6] In several instances this maximum is inferred rather than observed. Twenty of the curves extend to eighteen years, twenty-one around seventeen years, and the remaining four to about sixteen years. The last four are accepted since they distinctly show the attainment of an early maximum. (See case 9164 and compare with case 2301.)

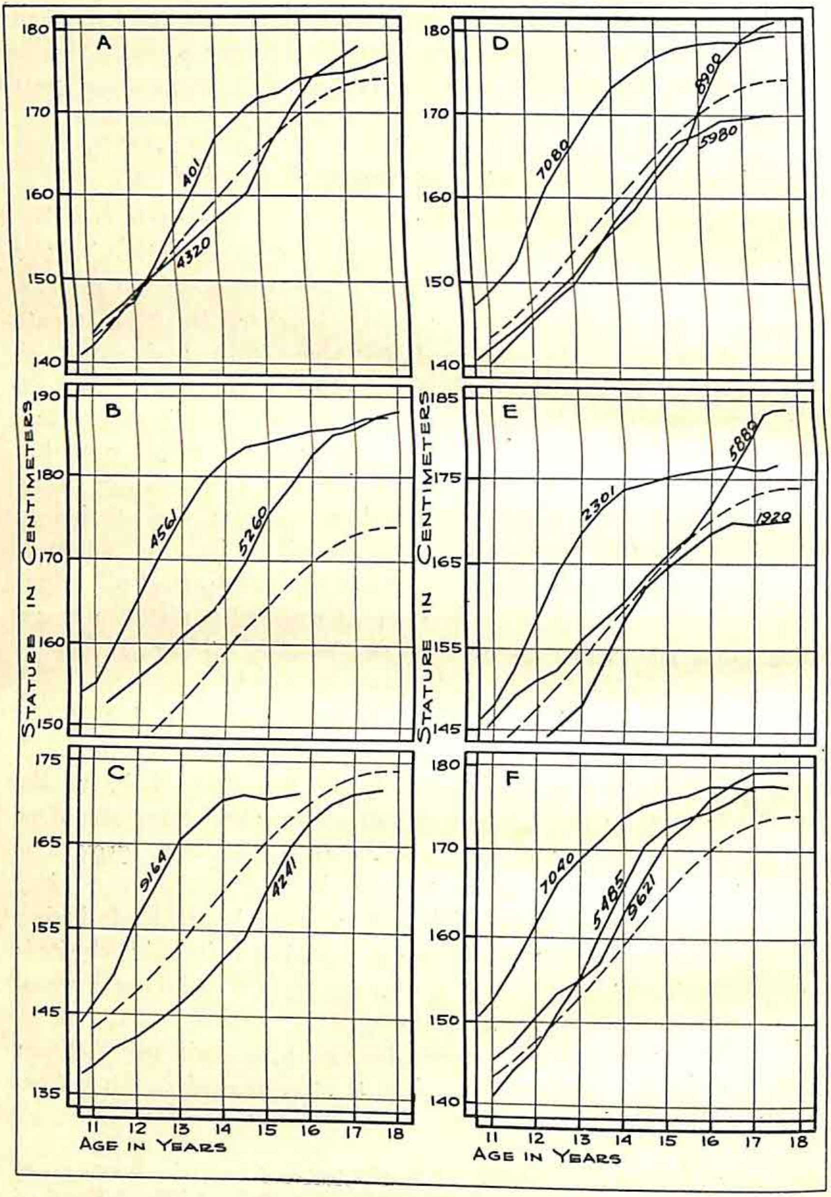

Figure 26. Individual stature curves for fifteen Iowa City white males are given. - - - represents the mean curve for stature. A discussion of the growth contrasts exhibited in this graph will be found on pages 114-115.

Stature,* Centimeters	Cases	Mean		Range			
		Years	Months	Years	Months	Years	Months
	Eleven Years						
Tall (more than 148.3)	5	15	1	14	3 to	16	3
Medium (136 to 148.3)	35	16	0	13	10 to	17	2
Short (less than 136)	5	16	7	16	3 to	16	11
	Eighteen Years						
Tall (more than 181.3)	6	16	2	15	3 to	17	2
Medium (167.7 to 181.3)	35	15	11	13	10 to	17	1
Short (less than 167.7)	4	16	2	15	1 to	16	11

*In this tabulation maximum adolescent stature is read at 3 cm. below stature at eighteen years.

The findings are similar to those for the preceding topic. On the average, boys who are tall at eleven years of age attain their stature at eighteen minus three centimeters one year and one-half earlier than do boys who are short at eleven years of age. This confirms the finding of Baldwin that

> "As a rule tall boys . . . reach their periods of maximum adolescent stature earlier than do short ones." (1, p. 92)

The overlapping is such, however, that the range for the medium group extends both beyond the lower end of the range for the tall group and beyond the upper end of the range for the short group.

The tall, medium, and short groups at eighteen years cannot be differentiated, either in mean or range, with reference to the time maximum adolescent stature was reached.

Constancy of Position in Group

The relative constancy of the tall, medium, and short stature groups will first be considered. In terms of the Baldwin-Wood standards, during the period from eleven to eighteen years, seventeen of the forty-five cases (38 per cent) show a change from one to another of the three crude stature classifications. Four cases fall in the medium group at eleven years of age, in the tall group between thirteen and fourteen years, and in the medium group again at eighteen years. Four other individuals are "tall" at eleven and fourteen years but fall to "medium" at eighteen years. Another group of four boys are medium at eleven and fourteen, yet enter the tall group before eighteen years. Of the five remaining boys, two are short at eleven and fourteen and medium at eighteen; one is medium at eleven and fourteen and short at eighteen; and one is tall at eleven, medium at fourteen, and tall at eighteen.

The findings for two other analyses of individual stature curves are pertinent. Fleming states:

> "Some children who till puberty promised to be very tall were checked at that age and grew less than others, thus bringing them into line with the norm. Others who had shown unusually small growth shot up at that age." (8, p. 47)

Baldwin writes:

> "With both boys and girls the curves assume a railroad appearance; each individual boy and girl holds approximately his or her relative position in the group for the periods from six to 17 years of age, with little crossing of the individual curves . . . In brief, tall children do not become short; neither do short children, as a rule, become tall under normal conditions." (1, p. 73)

The present study confirms Fleming's finding. It also confirms Baldwin to the extent that tall children are not found to become short or short children to become tall. The rather rigid constancy of stature groups suggested by Baldwin's use of the phrase "railroad appearance" is found between six and eleven years but not between eleven and eighteen years.

It appears that graphic presentation of a series of contrasting curves will strengthen the findings for stature groups and show more vividly the degree to which individual white males do not hold their "relative position in the group" during the adolescent years.

Figure 26 gives fifteen individual stature curves for Iowa City white males. Section A of this figure gives the curves for cases 4320 and 401. The former is taller than the latter at eleven and eighteen years but is 10 cm. shorter at fourteen years. This is not a unique contrast. The curves for at least six pairs of individuals could be presented, each pair showing approximately the same stature at eleven years and a divergence around the fourteenth year to the extent of 10 to 12 cm. or roughly one and one-half standard deviations.

Sections B and C of Figure 26 each show curves for two individuals who are 16 to 18 cm. apart in stature at fourteen years but who approximate the same adult stature. Both portray a common finding. It would be possible to present a minimum of twelve of the forty-five curves paired with regard to stature at eighteen years and yet, between the thirteenth and fourteenth years, showing a difference equivalent to two standard deviations or more.

Section D of Figure 26 shows three individual curves. Cases 8900 and 5980 approximate the same stature between eleven and fifteen and one-half years but diverge in excess of one and one-half standard deviations at seventeen and one-half years. Cases 7080 and 8900 are about 17 cm. apart at fourteen years and near the same stature at seventeen and one-half years.

Cases 5880 and 1920, shown in Section E, are over one standard deviation apart at twelve and one-half years, approximate each other at fifteen years, and are nearly 2.5 cm. apart at seventeen and one-half years.

Section F includes curves for cases 7040 and 5485. These two curves are separated to the extent of almost two standard deviations at eleven years, whereas at seventeen years the difference is less than .1 cm.

CHAPTER V

SUMMARY AND CONCLUSIONS

This study purposes a description of the growth rhythm for each of eighteen anthropometric measurements on Iowa City white males between the age limits of birth and eighteen years. Two primary aims of the investigation are (1) to obtain, analyze, and compare mean "course of growth" curves and mean "percentage rate" curves for the eighteen physical dimensions, and (2) to examine individual curves for stature, both from the standpoint of correspondence to the mean stature trend and with reference to the possibility of predicting growth in stature.

THE DATA

The data were gathered over a fourteen year period by the anthropometric staff of the Iowa Child Welfare Research Station. They consist of 93,232 measurement values on 1,243 Iowa City white males lying within the normal zone for physical build.[7]. Besides being homogeneous with regard to geographic location, sex, and bodily nonpathology, the 1,243 individuals constitute a group that is somewhat favored economically and culturally and but slightly diverse racially. The measurement values are distributed among the following eighteen measurements: stature, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse and antero-posterior diameters of the thorax, thoracic circumference, body weight, maximum head length and breadth, bi-condylar diameter of left femur and left humerus, strength of grip, breathing capacity, and thickness of skin and subcutaneous tissue at thorax front and back and at upperarm front and back.

MAJOR FINDINGS

Mean "course of growth" trends exhibit the following findings:

1. Four phases of alternate quickening and slowing of growth are revealed for stature, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse and antero-posterior diameters of thorax, thoracic circumference, and body weight. In general,

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[7] The individuals considered to lie outside the "normal zone for physical build" are those whose records bear the mark "physical deformity" or "endocrine disturbance."

there is a period of rapid growth extending from birth to two years, a period of slow growth between two and eleven years, a second period of rapid growth from eleven to fifteen, and a final period of slow growth between fifteen or sixteen and eighteen years. These "general type" curves differ markedly as to the form of their second phase. This segment is convex for the stature and sitting height trends and concave for the trends of body weight and thoracic circumference. The trends for the remaining four curves show gradation between convexity and concavity.

2. There are three pronounced convex cycles for bi-condylar diameter of left femur and left humerus. The first cycle spans the years from birth to six, the second reaches from six to eleven, while the third extends between eleven and eighteen.

3. A two phase or "neural type" of growth is shown for maximum head length and maximum head breadth. There is a phase of rapid accretion below about two years and a phase of slow and irregular progression above this age.

4. There are three roughly convex cycles between one and one-half months and ten years for the four measurements of skin and subcutaneous tissue. The four minima of these cycles occur at one and one-half months and at approximately two, six, and ten years. Beyond ten years the two thorax curves ascend, each attaining an absolute magnitude in excess of that found at any previous age. The two upperarm trends ascend from ten to eleven years and then commence to descend, each falling to a mean magnitude at eighteen years lower than that found at any point between three months and this age.

Mean "percentage rate" curves show the following:

1. There is an initial steep descent during the three quarterly intervals between one and one-half months and ten and one-half months for the full sixteen dimensions studied at this age. This common descent takes a concave course, indicating that the decline in growth rate proceeds at a diminishing pace with increasing age.

2. A primary minimum during the first quarter of the second year is shown for stature, sitting height, bi-deltoid diameter, antero-posterior diameter of thorax, body weight, bi-condylar diameter of left femur, and skin and subcutaneous tissue at upperarm front.

3. A pronounced dip appears at approximately six years for maximum head breadth, maximum head length, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse diameter of

thorax, skin and subcutaneous tissue at upperarm front, at thorax front, and at thorax back.

4. There is a convex arc, with its crest during the thirteenth or fourteenth year and its terminals during the eleventh year and during the seventeenth or eighteenth year, for stature, sitting height, bi-deltoid diameter, bi-trochanteric diameter, transverse and antero-posterior diameters of the thorax, thoracic circumference, body weight, bi-condylar diameter of left femur and left humerus, strength of grip, and breathing capacity.

5. A minimum appears during the eleventh year (indicative of a "low" in relative growth rate) for every measurement analyzed except the four for thickness of skin and subcutaneous tissue. These latter, in contrast, show a marked increase in percentage rate during this year.

Individual "course of growth" curves for stature indicate that:

1. At least 95 per cent of the stature trends for Iowa City white males are of the same general form between six and eighteen years as the mean trend for stature. However, these individual stature sequences differ from the mean curve in two respects: The change from retardation rate to acceleration rate is more sharply defined, and is variously timed over a four to five year age range.

2. There is little crossing of the individual curves between six and eleven years of age. In consequence, the T-score or percentile technique furnishes a reasonably refined instrument for predicting the stature of the individual Iowa City white male throughout this period. For forty cases the maximum error of prediction over the five year span is four and one-half centimeters; 80 per cent of the prediction errors are not in excess of two and one-half centimeters; the average error of prediction for the entire series is one and one-half centimeters.

3. Prediction of individual stature throughout the period from eleven to eighteen years is a precarious task. The beginning of adolescent acceleration occurs over a four or five year range. Individuals of the same stature at eleven years are commonly ten to twelve centimeters apart during the fourteenth year; individuals who differ in stature by fifteen centimeters during the fourteenth year not infrequently approximate each other in stature at eighteen years of age.

BY-PRODUCT CONTRIBUTIONS

In the realization of its primary aims, this investigation makes several by-product contributions. Six of these will be enumerated here.

1. Norms, in the form of arithmetic means, are given at successive age intervals between one and one-half months and eighteen years for sixteen anthropometric dimensions and between approximately three or six years and eighteen years for two additional measurements. The normative usefulness of the 529 means is enhanced since each is supplemented by the standard deviation and range for the distribution it represents.

Three qualifying statements are relevant in this connection. (1) It should be recognized that the norms are specifically valid for a group of Iowa City white males. Such selective factors as sex, geographic location, socio-economic status, and racial stock ought not to be overlooked when using norms. (2) In view of paucity of observations, the norms for certain measurements are regarded as tentative. This applies to the four measurements of skin and subcutaneous tissue and, in lesser degree, to the means for bi-condylar diameter of left femur and left humerus. (3) The means for the first nine or twelve months are considered to furnish only crude approximations at each quarterly interval. This follows from the rapidity of growth characteristic of these months.

It appears that this is the first study to provide means over the entire period from birth to eighteen years for bi-deltoid diameter, bi-trochanteric diameter, bi-condylar diameter of left femur and left humerus, transverse and antero-posterior diameters of the thorax, sitting height, and four measurements of skin and subcutaneous tissue.

2. Empirical formulae are presented which graduate the mean values for stature, thoracic circumference, body weight, maximum head breadth, bi-condylar diameter of left femur, and breathing capacity. Application of the six derived equations yield mean errors of prediction, disregarding sign, of .67 cm., .35 cm., .64 kg., .03 cm., .07 cm., and 5.8 cu. in. respectively. Such "goodness of fit" indicates that the equations (though shown to be inadequate for use in obtaining instantaneous velocity curves) are sufficiently refined for most purposes of interpolation and prediction.

3. Skewness and kurtosis values are given for a series of distributions on thoracic circumference. These values support the generalization that below seven years of age the distributions may be regarded as symmetrical and mesokurtic, while between seven and fifteen years the distributions are significantly leptokurtic and skewed in the positive direction. The peak of positive skewness and leptokurtosis is reached at twelve years.

4. A single coefficient of relative variability is derived and presented for each of the eighteen measurements. These coefficients enable comparison of one measurement with another. Age to age differences within a given measurement are also discussed.

5. Critical evaluation is made of the curve fitting and algebraic differentiation method of studying growth rates, and of the Courtis "universal law" method of predicting individual growth. It is found that the former is not applicable to the unitary study (from birth to eighteen years) of human growth rates for bodily dimensions. The latter is considered unsuited to the prediction of individual growth in stature for white males between six and eleven years.

6. A variety of growth contrasts is made. Two methods of contrasting mean growth give findings typified by the following statement: The average Iowa City white male doubles his stature between birth and six years of age; one-half of the mean stature attained at eighteen years is reached at about two years of age by the average Iowa City white male. Contrasts for the purpose of revealing individual differences in the same measurement are also given. It is found, for example, that the boys ranking at the upper end of the distributions for head breadth at about one year of age have wider heads than the boys at the lower end of the distribution for eighteen years of age.

RESEARCH LEADS

A few of the problems for further research upon which this investigation appears to focus attention will be briefly suggested.

First, what percentage of the individual curves for, say, bi-trochanteric diameter or bi-condylar diameter of the left femur show the same general form as their respective mean curves? Figure 25, Section B gives evidence of the fact that measurement inaccuracies[8] make it impossible to answer this question at present for bi-trochanteric diameter. Likewise, but for a different reason, the question cannot be answered for bi-condylar diameter of left femur. Seriatim observations on this measurement are not yet available for more than three year segments of the curve. Each of these illustrations is used to represent the situation for a series of measurements. It appears, therefore, that a conclusive answer to the generalized question must necessarily follow a considerable lapse of time during which frequent and precise seriatim measurement values are being accumulated.

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[8] It is probable that fluctuation in the thickness of the skin and subcutaneous tissue covering the skeletal landmarks is also a factor.

Secondly, the mean percentage rate curves for fourteen of the measurements studied are found to show a primary minimum during the eleventh year. The question arises: What percentage of the individual trends for each of these measurements is characterized by a corresponding decrease in relative growth rate during this year? The individual curves available do not permit a reliable answer to this question since they are based on semiannual measurements. Measurements at such intervals are too far apart for accurate study of growth rates because (1) the measurement values are subject to appreciable error, and (2) the changes in rate at this age are a function of comparatively small differences in absolute magnitude. The answer to the question must await careful seriatim measurement at bimonthly intervals between nine years and the beginning of the adolescent acceleration.

Such bimonthly measurement of a group of white males for a selected number of dimensions would lead to many other research contributions. For instance, it would make possible the refinement of our knowledge of the adolescent acceleration for various dimensions, and could be used to relate this acceleration to the amount and form of the pubic hair, to estimated endocrine balance, and so forth.

Thirdly, more detailed analysis of the thoracic dimensions (transverse diameter, antero-posterior diameter, and circumference) and of the four measurements for thickness of skin and subcutaneous tissue might show an inverse relationship between these two types of measurements during the third year. The present investigation finds a primary minimum for the three thoracic dimensions and a major maximum for each of the measurements of skin and subcutaneous tissue fluctuating over three quarterly intervals within this year. While month by month analysis may not support the hypothesis of an inverse relationship either for the group or for the individual, the study would be of value since it would at least yield more exact information on the form of the growth trends. Further, the values for the two thorax diameters could be used to contribute to the literature on the change in the contour of the thorax.

Fourthly, the skewness and kurtosis findings for thoracic circumference indicate the need for a like description of the distributions for other anthropometric measurements. The problem might also be expanded to include an intensive inquiry into the relation of skewness and variability to rate of growth.

Finally, the most obvious channel of research suggested by this study is a parallel investigation on white females. Not only would this be valuable in itself, but it would yield the necessary trends for a comparative analysis of the sexes in regard to "rhythm of growth."

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APPENDIX

ANTHROPOMETRIC MEASUREMENT TECHNIQUE USED AT THE IOWA CHILD WELFARE RESEARCH STATION[1]

Stature

During approximately the first two years following birth, height of necessity is taken in the reclining position. The instrument used is the Baldwin Measuring Board for Infants. The infant is placed on his back in such a position that the head makes firm contact with the fixed upright of the board, while the trunk rests on the base of the board and in line with its long axis. While an assistant holds the head and shoulders in position, the anthropometrist straightens the knees and holds the feet together. The latter completes the measurement by bringing the sliding upright firmly against the soles of the feet and reading off the crown-heel length from the millimeter scale.

Beyond the infancy zone this measurement is taken in the erect position. The Baldwin Paper Measuring Scale and Square are the instruments used. The subject stands straight with heels together. Heels, buttock, upper part of back, and head are against the wall to which the scale is attached. The arms are hanging at the side in a natural position and the head is held on the Frankfort Horizontal. The anthropometrist so places one face of the square against the scale that the other face is horizontal with the floor. The square is then brought down firmly against the head of the subject, the hair being crushed until the square is in contact with the head, and the reading taken.

Sitting Height

Infants are measured in the reclining position and older subjects in an erect sitting position. The instruments are the same as for stature. With infants, the procedure given for crown-heel length is modified only in that the hips are flexed at right angles to the trunk (the knees also being naturally flexed) and the sliding upright is moved up firmly against the buttock. The procedure with subjects beyond the infant zone is as follows: The subject sits on a horizontal and resisting bench 30 or 40 cm. high, the height being determined by the stature of the subject. The knees are flexed and spread apart, the ankles crossed, and the hands rest on the lap. The posterior aspect of the trunk makes contact with the scale both at the sacral region and at the thoracic region. The square is brought down firmly on the vertex (the highest median point of the head when held on the Frankfort Horizontal) and the measurement recorded as the distance in millimeters from the surface of the seat to the vertex.

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[1] This discussion draws heavily upon two previous descriptions of Iowa Child Welfare Research Station physical measurement technique, Baldwin (1, Chapter 2) and McCloy, C. H.: [A Revision and Extension of] III. Instruments, by Bird T. Baldwin. Unpublished manuscript. Pp. 14 ms. The treatment of Baldwin, in turn, is especially dependent on Hrdlicka (12, p. 10-88), while that of McCloy draws also on Martin (15, p. 117-231) and on Franzen (9, p. 108-110) for technique of measuring skin and subcutaneous tissue.

Bi-Deltoid Diameter

The standardized large sliding calipers are used as the anthropometric instrument. Subjects too young to be measured in the erect position are supported in the sitting position. The arms are hanging at the side. With subjects sufficiently developed to assume the erect position, the measurement is usually taken from the rear. Since the length of the clavicles modifies the measurement considerably, the subjects measured erect are requested to draw back the shoulders until the scapulae lie approximately in one plane. The measurement is the distance over the deltoid muscles, with the prominent tuberosity of the head of each humerus bone below the acromion processes as the landmark. Before reading the measurement, the pressure of the calipers is increased until the resistance of the bones is felt appreciably.

Bi-Trochanteric Diameter

This measurement is taken with the large sliding calipers, with the prominences in the region of the trochanters for the two terminal points. With infants the legs are extended and held parallel. With older subjects, likewise, the legs are together and the feet parallel. The pressure is such that considerable resistance of the bones is felt.

Transverse Diameter of Thorax

The instrument used is the large sliding calipers. The infant is supported in a sitting position. The older subject stands in an easy, natural manner, the arms relaxed in order to reduce tension of the thoracic musculature. The anthropometrist stands in front of the subject and applies the arms of the calipers to the lateral aspects of the thorax in such a way that they lie in the same horizontal plane as the nipples. Moderate pressure is maintained against the two sides during inspiration and expiration by means of an accompanying movement of the free branch of the calipers with the thumb. The scale is watched carefully and after two or three inspirations and expirations the medium between the greatest and shortest distance is recorded. Care is taken to see that the arms of the calipers are not extended posteriorly to project over the latissimus dorsi muscles.

Antero-Posterior Diameter of Thorax

Here again the large sliding calipers are used. The measurement is taken so that the fixed arm of the calipers is placed just below the inferior angle of the scapulae and the movable arm is applied to the anterior aspect of the thorax at the nipple level. Repeated measurements are taken during inspiration and expiration and the medium between the largest and the smallest caliper reading is recorded.

Thoracic Circumference

A steel millimeter tape is used in taking this measurement. The nipple line serves as the anterior landmark. The tape is placed around the thorax at right angles to the spinal column. This usually means that, posteriorly, the tape rests just below the inferior angles of the scapulae. The tape is pulled only sufficiently tight to insure complete contact all around. The medium value during normal respiration is recorded.

Body Weight

Weight, in common with all other measurements, is determined with the subject nude. The scales used in the anthropometric laboratories of the Iowa Child Welfare Research Station are Buffalo, Fairbanks, and Continental types, with double or triple bar beams. Table scales are used with infants and platform scales with older subjects. Body weight is ascertained and recorded in kilograms.

Maximum Head Length

The maximum glabello-occipital diameter is taken with the spreading calipers. Anteriorly the landmark is the glabella. Posteriorly the landmark is taken as the most prominent point of the occiput as shown by the maximum determinable spread of the branches of the calipers. The left branch of the calipers is applied to the anterior landmark and three fingers of the left hand so placed about the point of this branch as to form a ball and socket arrangement while holding the point in position. The right branch of the calipers is moved up and down and across from side to side on the back of the head until the maximum distance is encountered.

Maximum Head Breadth

The spreading calipers are used. The measurement is determined solely by the maximum breadth of the head above the supermastoid and zygomatic crests. The points of the calipers are moved backwards and forwards and up and down in the horizontal plane until the greatest width is found. The anthropometrist watches the scale and records the maximum distance.

Bi-Condylar Diameter of Left Femur

Here the large sliding calipers are used to measure the maximum outer diameter of the condyles of the left femur. The knee is flexed sufficiently to relax and largely remove the musculature at the lateral aspects of the condyles. The arms of the calipers bisect the thigh-calf angle as they are brought in contact with the bony prominences. Heavy pressure is used.

Bi-Condylar Diameter of Left Humerus

This measurement is taken with the large sliding calipers. The left upperarm is raised forward away from the body and the forearm is flexed at right angles to the upperarm. The arms of the calipers bisect the upperarm-forearm angle. Considerable pressure is used. Care is taken that the forearm does not move out of line with the arms of the calipers and turn in toward the midline of the body as the pressure is applied. The maximum diameter between the epicondyles is recorded.

Strength of Grip

The Smedley Hand Dynamometer is used for testing grip strength. The adjustable stirrup of the instrument is regulated in accordance with the size of the subject's hand. The subject is encouraged to exert the maximum strength possible. Care is taken to see that the arm of the subject does not come into contact with the trunk or lower extremity. Two trials are usually allowed with each hand and the best record (in kilograms) for each hand is recorded. The factors of motivation and comprehension of instructions make this measurement inapplicable with subjects younger than three years of age.

Breathing Capacity

The volume of lung capacity minus residual air is measured by means of the wet spirometer. The water in the spirometer is maintained approximately at room temperature (25° C.). The subjects are instructed to take the deepest possible inhalation and then to blow all of the breath possible into the instrument. During inhalation the subject is encouraged to take in all air possible and near the end of exhalation he is urged to keep on blowing. The anthropometrist keeps a watchful eye to see that an extra breath does not spuriously raise the record. Every subject is provided with a new, detachable wood mouthpiece through which to blow. Usually three trials are allowed. The measurement is recorded in cubic inches. The factors of motivation and of comprehension of instructions prohibit the use of this measurement during the early years. At the Iowa Child Welfare Research Station laboratories breathing capacity is not taken below five years of age.

Skin and Subcutaneous Tissue at the Thorax Front

This measurement, together with the three succeeding measurements, is taken with the fat calipers. In all four instances the flat, blunt-nosed blades of the calipers are held parallel to the long axis of the body or extremity of the subject.

Measurers in training use a standard bite of 20 mm. for infants and 30 mm. for all older males in taking this measurement. Experienced anthropometrists find the standard bite routine dispensable and thus judge the bite to be used from the firmness and amount of the subcutaneous tissue of the individual subject. The essential principle which all follow is that of placing the thumb and first finger some distance apart below the left nipple at the xiphoid level and of moving these digits directly toward each other. Care is taken that the digits do not tend away from the thorax as they approximate each other (or at any time following the pinch until the observation is recorded). The instrument is then applied to the tissue held between the thumb and finger and the measurement read off. The central objective is to measure a complete double layer of skin and subcutaneous tissue without including any muscle tissue.

Skin and Subcutaneous Tissue at the Thorax Back

The standard bite is 20 mm. for infants and 40 mm. for all older males. The measurement is taken below the inferior angle of the left scapula at the xiphoid level.

Skin and Subcutaneous Tissue at the Upperarm Front

This measurement is taken midway between the extremities of the left humerus over the biceps muscle. The standard bite is 20 mm. for infants and 30 mm. for all males from preschool age through senior high school.

Skin and Subcutaneous Tissue at the Upperarm Back

The standard bite here is 20 mm. for infants, 30 mm. for preschool males, and 40 mm. for all older males. The measurement is taken approximately at the midpoint of the shaft of the left humerus with the arm hanging in a relaxed position.

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